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ABSTRACT

Designed to assist in the dissemination of views about educational issues associated with engineering education and its incorporation in general education, this bibliography presents a review of the literature in engineering education under seven headings. These include: (1) engineering and higher education, the social context; (2) the relationship between engineering and the sciences; (3) the engineering curriculum in higher education, aims and objectives; (4) the place of design in the engineering curriculum; (5) practical training for the undergraduate engineers; (6) educating engineers for management; and (7) the status of engineers and engineering. The organization of items within each of the seven categories is chronological and each category is prefaced with introductory comments. The annotations are limited to works published in English and mostly relate to engineering education in British universities. An author index is also provided. (ML)

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TEACHING AND LEARNING

IN

THE THIRD CULTURE?

AN ANNOTATED BIBLIOGRAPHY OF ISSUES IN ENGINEERING EDUCATION

ROBERT FINNIGAN AND DAVID LAYTON

CENTRE FOR STUDIES IN SCIENCE AND MATHEMATICS EDUCATION

UNIVERSITY OF LEEDS

1984

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Engineering...embraces too many things for a man to be able to make himself perfectly master of it;...I find myself not more than half an engineer, after forty years of very hard study, and of the largest experience anyone ever had.

Vauban (1633-1707)
'the greatest of French engineers prior to the eighteenth century.'
[from: G.S. Emmerson, *Engineering Education - A Social History* (1973).]

INTRODUCTION

Although the subject of this bibliography is engineering education at undergraduate level, its origins are in the secondary school science curriculum. The articulation of these two fields of educational activity requires a word of explanation.

Well before the intervention of the Manpower Services Commission with its Technical and Vocational Education Initiative in the Autumn of 1982, it had become clear that many influences were at work to make the secondary school curriculum more related to the world of work and to practical problem-solving in real-life situations. An increased priority given to Craft, Design and Technology (CDT) in the curriculum;[1] a government sponsored injection of computers into both primary and secondary schools; a proliferation of work experience schemes and pre-vocational courses; and a Royal Society report[2] emphasising the need for practical applications in school science teaching were but some indicators of the direction of change. Not always well co-ordinated, and frequently under-resourced, the developments nevertheless seemed to point towards similar goals.

What did not seem to be realised widely, however, was that the goals were by no means new. Indeed, the historian David Reeder, in analysing previous efforts to establish a practical curriculum entitled his account 'A Recurring Debate'.[3] One need not follow Reeder back into the nineteenth century for instances. In the period following the Second World War secondary technical schools were established by a number of local education authorities, yet little trace remains today of their curriculum. Before they were overtaken by comprehensivisation, their lobby, the Association of Heads of Secondary Technical Schools, under the leadership of Edward Semper, seized the opportunity presented by the Crowther Report's advocacy of 'the alternative road' and the politicisation of technology by the Wilson government of 1964, to press the case for a major curriculum development project. This was to be the technological counterpart to the Nuffield Foundation Science Teaching Projects. The Schools Council's Project Technology followed (1967-72) but made relatively little impact on the secondary school curriculum at the time.[4]

Various reasons have been offered to explain such past failures to implement a curriculum for technological capability. The cost of equipment, teachers without industrial experience, and the incompatibility of project work with the everyday constraints of classroom life have all been invoked. More fundamentally, however, much previous effort was afflicted by lack of clarity about the educational potential of technology and indeed about the nature of the activity itself.

The word 'technologist' was not coined until 1854, although 'engineer' is of greater antiquity, especially in its military association. 'Technologist' therefore, postdates 'scientist' and 'physicist', products of William Whewell's neologising in 1840.[5] Attempts have been made to distinguish 'technology' from 'engineering', not least in the context of the work of bodies such as the Committee on Manpower Resources for Science and Technology in the 1960s. For many practical purposes, however, it is sufficient to regard 'engineering' and 'technology' as describing virtually the same area of activity, at least - as Michael Fores has pointed out - in the context of innovation in industry.[6]

Where a distinction has to be made - and it has been drawn with increasing sharpness over the past decade - is between science and engineering. The Finniston Report commented here on 'the misleading national tendency to

regard engineering as a subordinate branch of "science".'[7] The frequent assumption that technology is applied science and the use of expressions such as 'engineering sciences' have only served to reinforce this tendency. It was not until 1982 that the word 'Engineering' was inserted in the title of the Science and Engineering Research Council, previously the S.R.C. The administrative and political separation of technology from science, with the establishment of the Ministry of Technology in 1964, had been bitterly opposed by many leading scientists and was contrary to the recommendations of the Robbins Report. In the same way, the proposal to establish a 'Royal Society' for Technology to do for engineering what the Royal Society did so well for science met with scorn and hostility in the 1960s,[8] though by 1984 the Fellowship of Engineering, founded eventually in 1976, was in receipt of a government grant, on a par with the Royal Society.[9] In relation to these developments an influential pressure group for university engineering education and research has been the Engineering Professors' Conference, established in 1974.

Parallel to this political and economic emancipation of engineering from science, there have been significant academic developments. The history of technology began to emerge as a serious discipline in the late 1950s. The Society for the History of Technology was founded in 1958 in the U.S.A., and its journal, Technology and Culture, commenced publication in 1960. The British journal, History of Technology, first appeared in 1976 by which time the two leading English university centres of technology education and research, Imperial College and U.M.I.S.T., each had established chairs in the history of technology. Philosophy of technology followed the developments in history. Carl Mitcham's and R. Mackey's pioneering bibliography, the Philosophy of Technology, first appeared as a special supplement to the April 1973 issue of Technology and Culture.[10] The annual series Research in Philosophy and Technology edited by Paul T. Durbin commenced in 1978. By the mid-1980s a burgeoning literature in the philosophy of technology testified to the amount of serious inquiry into the nature of engineering and technological activity, as well as to the recognition that the activity was fundamentally different from science.

So far as the schools are concerned these developments have a direct and practical implication. If there is a distinct 'Technik', with characteristics which distinguish it from the sciences and humanities, should it not have a place in the general education offered by schools? Are there, indeed, three cultures, not two as C.P. Snow suggested, the third corresponding to the creative, problem-solving and productive activities of the engineer? Ought we not to recognise more clearly in curriculum terms that the fundamental difference between science and technology is social, a difference in values between a community whose sovereign value is 'knowing' and another whose ultimate goal is 'doing'? And if the answer to each of these questions is 'Yes', what problems arise in relation to teaching and learning in the third culture?

Interest in these questions was stimulated by previous research undertaken in the Centre for Studies in Science and Mathematics Education, University of Leeds. A project on the history of the secondary technical schools since the Second World War, and another on the politics of school science and technology over the same period, had demonstrated the persistence, as well as the difficulties, of attempts to create a more practically orientated secondary school curriculum.[11] From an historical perspective, the endeavours appeared to be badly coordinated, unevenly resourced and, frequently, vigorously opposed. Alternative and competing versions of 'school technology' were to be found. At one extreme of a spectrum there was open-ended project work involving creative design and craft skills;

at the other end there were analytical, formally taught courses on the applications of scientific principles in engineering contexts. The schools also had to contend with distinct traditions of craft and science teaching, staff in each category being trained in different institutions and accorded different status. Though a small number of schools made impressive contributions to the incorporation of 'Technik' in the curriculum, the post war efforts stopped far short of achieving a generalised solution. The situation was well summarised in 1960 by Edward Semper, one of the leading exponents of secondary technical education, who at that stage concluded that 'we have scarcely begun to develop a practical approach to education in our schools, that is, a practical education making progressively exacting intellectual demands'.[12]

More recent attempts to refashion the secondary school curriculum in a way which emphasises technological capability have brought into prominence again the need for clearer definition of the distinguishing characteristics of Technik and better understanding of its pedagogy. The richest single vein of professional involvement with these matters is to be found, not in schools, however, but in higher education at undergraduate level where engineering has been taught for many years. Accordingly a review of the literature of engineering education has been undertaken, starting in the 1950s and running through to the Finniston Report (1980) and beyond. The results of this review are presented under seven headings:

1. Engineering and higher education : the social context
2. The relationship between engineering and the sciences
3. The engineering curriculum in higher education : aims and objectives
4. The place of design in the engineering curriculum
5. Practical training for the undergraduate engineers
6. Educating engineers for management
7. The status of engineers and engineering.

Preliminary consideration of the subject of engineering education, and especially of the central issue of the distinctiveness of engineering compared with the sciences, suggested a number of these headings. Others were 'data generated' in that they emerged from the literature survey as educational issues about which engineers themselves had expressed concern. The scope of each of the seven issues is described briefly in the separate introductions to the bibliographic entries. No doubt if the time scale of the survey had been longer, additional categories would have been necessary. Thus the bibliography does not include any references to the educational possibilities and problems created by the use of computers in the teaching of design.

The survey was limited to works published in English and, indeed, most of the items relate to engineering education in British universities. Even so, the sources from which items have been culled are many and various. Although engineers and engineering have been the subject of a number of historical and sociological researches described in books, there are few book-length studies of engineering education, conference reports apart. As a result the majority of items have been found in a disparate journal literature. Here, the number of journals devoted specifically to engineering education is small, the European Journal of Engineering Education being a useful starting point, albeit of recent origin (1976). The International Journal of Mechanical Engineering Education has an altogether narrower focus in relation to both the engineering and educational issues considered. The publications of the major professional institutions of engineering proved to be an important source

of material, whilst general scientific journals such as Nature, The Advancement of Science and New Scientist also yielded relevant items.

Beyond these the quest led into both general and specialised engineering periodicals as diverse as The Engineer, Engineering, The Chemical Engineer, Energy World and Electronics and Power. From the educational side the issues were approached through general sources such as Universities Quarterly, Higher Education Review, Vocational Aspect and the Journal of the Royal Society of Arts as well as through more specialised outlets like Physics Education, Design Studies and Project. Historical, sociological and ethical aspects of engineering education, scarcely a rich vein, occasionally surfaced in Technology and Culture, Impact of Science on Society, and the Bulletin of Science, Technology and Society.

Apart from major reports such as those of the Chilver Committee on the Education and Training of Civil Engineers (1975) and the (Finniston) Committee of Inquiry into the Engineering Profession (1980), reference has been included to the results of recent research projects in the field of engineering education such as the Goals of Engineering Education Project, GEEP (1983).

Finally, two other sources of material deserve mention. A review of theses accepted for research degrees revealed a small number of relevant items and inaugural lectures delivered by newly appointed engineering professors were sampled when these incorporated the expression of definite views on university engineering education.

The organisation of items within each of the seven categories is chronological. In this way shifts in opinion and priorities with changes in the context of engineering education can be readily followed. Within a given year, entries are arranged alphabetically by author's surname.

With regard to secondary school education the period under review has seen significant changes in beliefs about the desirability of including some experience of 'the engineering dimension' in the curriculum. In the 1960s there was near unanimity that the best preparation for a university engineering course was the study of G.C.E. A-level mathematics and science subjects, especially physics. Beyond this, a little judicious careers guidance was all that was needed. The emphasis on mathematics and physics still exists. But in addition and in contrast, the discussion document Survey on Schools, Pupils and the Engineering Profession published by the Engineering Council in 1984 recommends that the Council should 'welcome and support' the inclusion of aspects of CDT into a common curriculum for all in secondary schools up to 16+, and should encourage the academic development of CDT in sixth forms 'to provide an alternative path for the intending engineer'. Similarly, 'the increasing use of microprocessors in schools' should be accompanied by an emphasis on 'their application in the engineering process'.[13] In short, the case for Technik as a basic component in the secondary school curriculum should at long last have a national champion with the Engineering Council declaring 'its intention to be the principal focus for all aspects of school/industry links which bear on its responsibilities for the profession of engineering' and to take 'all opportunities to comment on relevant policies and initiatives from Government and other organisations'.[14] Little evidence of attitudes hostile to engineering was found amongst pupils and teachers by the survey. At the same time, 'no clear coherent picture...of the engineering dimension as it exists within industry and the public service' was being presented in schools.[15] A continued emphasis on mathematics and science, as previously taught, would do little to alleviate this situation. The general problem

was 'not one of attitudes but of ignorance'.

The main purpose of this bibliography, then, is to assist in the dissemination of views about the educational issues which are associated with 'the engineering dimension' and with attempts to incorporate this in general education. Possibly, as Sir Brian Flowers has suggested, the very complexity of such aspects as creativity, design and innovation has hampered previous attempts to establish engineering as an established academic discipline.[16] The 'teachability' of 'creativity' and 'design' is something about which relatively little is known at school level, and the assessment of attainments in such areas poses difficult problems. If the bibliography serves to indicate areas where teaching and learning difficulties might exist and where future research in this neglected field of secondary education might be directed, it will have served its purpose.

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15. Ibid. p.65.

16. Sir B. Flowers, Engineering and the U.K. Science Research Council, Proc. of the Institution of Electrical Engineers, Volume 117 (6), 1970, 1192-1200.

1. ENGINEERING AND HIGHER EDUCATION : THE SOCIAL CONTEXT

The entries in this first section draw attention to the social context within which engineering studies in higher education have developed in post-war Britain. An underlying theme in much of the writing on this topic is the belief in a relationship between the extent and quality of engineering education on the one hand and the performance of British industry on the other. The phenomenon of relative economic decline in this period has led many, both within education and beyond, to consider the effectiveness of engineering education as an agent of economic and technological advance. This issue was obviously a major concern of the Committee of Inquiry into the Engineering Profession which sat from 1977-80 and produced the now famous Finniston Report in 1980. The works cited here reflect this concern, either explicitly or implicitly. They focus on the problems which have confronted engineering in its emergence as a 'respectable' academic discipline. In particular they highlight the tensions between the so-called 'pure' disciplines and applied studies within higher education, and the manifestation of this in the conflict between science and engineering. Some writers interpret this conflict in terms of long standing educational and social dispositions which have undervalued those skills and knowledge having a practical, or industrial, application, in favour of more academic pursuits.

* * *

KASTNER, L.J. 101

Education, Tasks and Outlook of the Engineer

University College Swansea, Inaugural Lecture, 1950

> The days are gone when work in pure science was viewed as always of much higher intellectual quality than applied research. It has at last become evident that the activities of the applied scientists are in a very real sense complementary to those of the fundamental research worker. Both tackle problems requiring the same diligence, skill, and tenacity of purpose for their solution.

See also 301, 501, 601.

ASHBY, E. 102

Technology and the Academics (Macmillan, 1958, pp.118)

> Britain neglected scientific education until late into the nineteenth century and has continued to neglect technical education until the last few years. In general the universities have tolerated the development of technological education but it has not been assimilated. They have been influenced by the traditional beliefs in the superiority of theory over practice, and in the superiority of an education in the classics and humanities. The problem in technological education is not one of subject content, to be remedied by including a smattering of information about the humanities; the problem is one of approach, since at present the study of technological subjects is too far removed from the real world. A technologist above all others is concerned with his social environment since all his work has social implications. The basis of a liberal education in technology must be the study of its social effects.

CLAUSEN, H. 103

The borderland between science and engineering

The Engineer Vol.211, 1961, 896-98

The old cleavage of thought in Britain between the arts and sciences has been replaced to some extent by that between science and technology. It is unfortunate that in this cleavage between science and technology it is usually assumed that scientific activities are in some way superior. But if technology is 'the philosophy of craftsmanship', it is an activity with a far higher humanistic content than science, being in reality the essential link and meeting point for coordination between the arts, the sciences, the humanities, and industry and commerce as well. The effective fulfilment of advances in science, therefore, is entirely dependent on engineering activity.

See also 205, 405.

JACKSON, Sir W. 104

The Partnership between Science and Electrical Engineering

Imperial College of Science and Technology, Inaugural Lecture, 1962

Some scientists regard the process of translation of the result of scientific work into engineering achievement as a markedly lower grade activity than their own, and generate in their better students an antipathy towards participation in this process. The pure scientist should recognise that the conduct of applied research and development, and the speedy translation of its results through engineering design and manufacture, can make severe intellectual demands, equal to those required in his own sphere, and involve problems of human relationships from which he is largely protected. Yet, engineering activity still lacks a public prestige commensurate with that enjoyed by pure science.

BOSWORTH, G.S. 105

Towards creative activity in engineering

Universities Quarterly Vol.17(3), 1963, 286-97

Universities are the traditional home of scholarship and this approach is needed even in science and engineering. But provision must be made not only for the acquisition of knowledge and techniques but also for practice in using them to solve real life problems. Practice carries overtones of vocationalism and manual crafts associated with institutions regarded as inferior to those where the scholarly approach is dominant. Scholarship is identified with high academic status and both students and teachers currently aim away from the real world of engineering towards a stylized science which is neither scholarship nor useful art.

See also 410.

ARGLES, M. 106

South Kensington to Robbins: An Account of English Scientific and Technical Education since 1851 (Longmans, 1964, pp.178)

A history of scientific and technical education from the Great Exhibition to the Robbins Report demonstrates that the organisation of technological education has faithfully reflected the development of society. The early system of local initiatives and modest government

encouragement has given way to increasing state intervention and attempts to create a national system of technological education. Development has been characterised by neglect and indecision on the part of political institutions and industry, and the fact that technical education came to be generally regarded as something of a markedly inferior status. Social and technological change is now so rapid that educational planning must look at least one generation ahead; in technology this will not be successful unless it is systematised and coordinated with other forms of education. Technological training must impart traditional broad human values so that students have some realisation of the social goals of science and technology.

LINSTEAD, Sir P. 107

Science and technology - separate or together?

The School Science Review Vol.46, 1965, 281-93

It has been argued that the greater prestige which technology needs could be supplied by a new high level institution - a Royal Society of Technology. This could do for technology what the Royal Society does so well for science. There are powerful arguments against such a proposal. It would add to a cleavage which should be sealed and not widened. It would produce a Society which would tend to be regarded as a poor relation. It is desirable to recognise the essential unity of pure and applied science by maintaining a learned academy which can harbour both. The way ahead lies in the election of more technologists, or scientists from the applied field, to the Fellowship of the Royal Society. This would enable the Royal Society to speak for both science and technology and should greatly enhance the prestige of applied science.

See also 214.

GERSTL, J.E. and HUTTON, S.P. 108

Engineers: The Anatomy of a Profession (Tavistock, 1966, pp.229)

One reason for the low status of the engineering profession in Britain is the attitude within the universities towards engineering. In the conservative and rarefied atmosphere of universities, science was a relative newcomer as an academic discipline. Until recently, classics and arts were regarded as much higher forms of academic life. Similarly with the latecomer, engineering: in the older universities it was regarded as hardly a fit subject for university study. This attitude persists as a form of snobbism that regards engineering as inferior to science; it can be explained partly in terms of ignorance and partly as a hangover from the 19th century. Just as science has to compete with the arts, so engineering has to compete with science, which at the moment has more glamour and respectability.

See also 215, 710.

HILKEN, T.J.N. 109

Engineering at Cambridge University 1783-1965 (Cambridge U.P., 1967, pp.277)

Engineering entered Cambridge towards the end of the 18th century as a subject of interest to a professor whose statutory duty was to find a cure for gout. Gradually it came to be accepted as part of a liberal education (as an optional subject for the Ordinary Degree) and later

as a discipline in its own right when the Mechanical Sciences Tripos was established in 1892. The development of teaching and research in engineering is related to the general pattern of these activities at Cambridge, and an indication is given of the university's particular contribution to the development of higher technology in Great Britain. Concludes with a description of the scope and nature of the teaching and research being carried out by the Cambridge Engineering Department in 1965.

VIG, N.J. 110

Science and Technology in British Politics (Pergamon Press, 1968, pp.190)

The 'science policy debate' of 1959-64 and its results constitute the bulk of this study. Three general aspects of the debate are examined:

1. The scale, balance and effectiveness of government support for civil research and development, particularly in relation to economic growth and modernisation.
2. Higher education and the supply of scientific and technological manpower.
3. The organisation of government for support and conduct of civil research and development and for rational allocation of scientific resources.

The basic question under consideration is how science is to be related to political purposes and values, and to the economic and constitutional system.

CHERRY, C. 111

The educational values of technology

Schools Council Project Technology Bulletin Vol.2(9),1969, 99-102

Spheres of thought labelled 'pure', such as mathematics and physics, have succeeded academically by separating off their systems of thought from all the vagaries of human beings. (Thus 'pure science' suggests a closed and sufficient system of thought while 'applied science' suggests impurity and adulteration.) As a result studies which must by their nature relate to human needs and values have been placed on an academically lower plane. Of these, one that has appeared rather late on the academic scene is Technology - the design of artefacts for people - a subject which has never really found its rightful place but has tried to latch itself on to science in its search for academic respectability.

See also 216.

GANNICOTT, K.G. and BLAUG, M. 112

Manpower forecasting since Robbins: a science lobby in action

Higher Education Review Vol.2(1), 1969, 56-74

The work of the Committee on Manpower Resources for Science and Technology lacks intellectual substance. In particular the committee has failed to make its case for a long-term shortage of scientific manpower. Its measure of demand ignores the realities of the labour market and relies on dubious surveys and misleading classification techniques. Its concept of 'needs' proves to be nothing more than an assertion of a value judgement that more scientists and technologists would benefit the country. This has nothing to do with the art of manpower forecasting and is simply the special pleading of a science and engineering lobby.

HALL, M. 113

Research v. Industry

Higher Education Review Vol.1(2), 1969, 28-44

The tendency for manpower statistics to bracket together scientists, engineers and technologists sidesteps a central issue - whether the concentration of the universities on science, and the moderate role they play in training engineers, is, at the present stage of industrial development, defensible. By convenient aggregation of university output of scientists and engineers, the impression can be given that the academic world is reacting effectively to national needs. However, there is in reality a grave disparity between university output and the needs of the economy. The output is preponderantly scientific, although it is hard to find anywhere in the economy a comparable level of demand for scientists as opposed to engineers and technologists.

WALLACE, P.J. 114

Is the engineer undervalued by society?

The Engineer Vol.229, 18 September 1969, 52-3

Engineers' concern about status derives from the differential attitudes of society towards engineers and scientists. Society has chosen to thrust upon the scientists credit for the achievements of engineers. Diminution of regard for the engineer was not the work of either the press or public, and certainly not of the scientists. The responsibility lies with the engineers themselves, who have failed to emphasise the crucial dependence of material civilisation on engineering, and instead sought to extol the superior claims of science. Some sought to protect their status by debasing the status of others, notably their predecessors who were dismissed as mere 'mechanics' because their acquaintance with the sciences had been intuitive rather than formal. The damage wrought by this fallacy may well prove irremediable.

See also 217, 417.

FLOWERS, Sir B. 115

Engineering and the U.K. Science Research Council

Proceedings of the Institution of Electrical Engineers Vol.117(6), 1970, 1192-1200

After many years science may now be regarded as an intellectual discipline culturally assimilated into university life; but engineering and technology still reside there rather uneasily, awaiting full recognition of their proper role in the university environment. The novelty and complexity of such aspects as creativity, design and innovation have hampered attempts to regard engineering as an established academic discipline.

See also 218.

CHARLTON, T.M. 116

The development of engineering education

The Aberdeen University Review Vol.44(4), 1972, 331-38

It is unfortunate that continental developments in advanced engineering education during the eighteenth and early nineteenth centuries received so little attention in Britain. Although leading engineering practitioners formed societies for the advancement of their 'art',

full time advanced education in applied science seems to have had a negligible part in their deliberations. The engineering profession in the nineteenth century seemed indifferent to the development of university courses in engineering science. As a result much of the technological advantage gained through industrialisation has been lost. The neglect of advanced education for engineering and the consequent failure to establish engineering as a learned profession, has had a detrimental effect on the recruitment of sufficient outstanding young people in more modern times.

See also 327.

FORES, M.J. 117

Engineering and the British economic problem

Quest No.22, Autumn 1972, 21-23

The Royal Society's recent history is characterised by a neglect of the useful arts referred to in its original charter, and a concentration on natural knowledge. The recent return by some members to an interest in the present ill-termed 'applied sciences' has not been successful since today's natural scientists know far too little about engineering and technology to speak with authority on these subjects. So they are not well qualified to discuss the role of engineering and technology in the British economic problem.

See also 220,715.

EMMERSON, G.S. 118

Engineering Education - A Social History (David and Charles, Newton Abbot, 1973, pp.384)

The history of engineering education cannot be understood if divorced from the history of engineering, and the history of engineering cannot be understood if divorced from the history of society. An attempt is made here to take account of all three, and to see engineering education or the progenitors of engineering education in the social context. The study focusses on North America, Western Europe (including Great Britain) and Japan since the 17th century. In more recent times the quest for the ideal engineering curriculum has led to perpetual and cyclical argument throughout the industrialised world and there is every sign that a state of flux is destined to be the curriculum's normal condition for the foreseeable future. The engineer is a vital component in the scientific-technological revolution which is the dominant concern of the industrialised nations today. Engineering education shares the crisis which confronts these societies.

TAYLOR, Sir J. 119

The Scientific Community (Oxford U.P., 1973, pp.79)

The institutionalisation of science has resulted in intense specialisation; in the artificial separation into pure and applied science and technology and a further separation from engineering. Science has achieved status through the Royal Society, and through its establishment in the universities. The dichotomy of science into pure and applied has resulted in a preponderence of academics in the Royal Society's fellowship which includes few technolgists. As a result, technology has not enjoyed the status that pure science has acquired

from its identification with the Royal Society. However, there is merit in the view that the Royal Society should remain an independent body of high status and integrity to maintain and further the pursuit of pure scientific knowledge; the 'dilution' of the Society by technologists and engineers would inevitably lead to a concentration on the useful rather than the fundamental.

LAYTON, E.T. 120

Technology as knowledge

Technology and Culture Vol.15(1), 1974, 31-41

The difference between science and technology has been seen in Platonic terms as the distinction between two philosophical ideas - knowledge and art. From this point of view it would be absurd to think of knowledge flowing from technology to science. But if the difference is seen in social terms, as values held by different communities, the result is a symmetric model of science - technology interaction. There is no contradiction in the assumption that knowledge might flow from a community that values doing to one that values knowing. Thus, the idea that science generates the knowledge employed by technologists is insufficient. Science may well influence technology in this way, but this does not provide an adequate explanation of most technological change.

See also 425.

BAKER, Sir J. 121

The engineer and survival

Advancement of Science New Issue No.2, 2 September, 1976, 2-6

During the Second World War the scientists who made a reputation did so as engineers not as scientists: at the same time they developed a political skill or influence not matched by the engineer. Following their success in war the scientists made no attempt to take over and supplant the engineer, or even to join him in his creative work; instead they used their political influence to perpetuate their own kind and to increase their facilities, in the mistaken belief that this would enrich us all. Hence a long line of government committees, manned predominantly by academic scientists, spoke of the 'qualified scientist and engineer', despite the reality that the two groups have quite dissimilar aims.

See also 223, 719.

COTGROVE, S.F. and WALSH, J.D. 122

Total technology - the theory and some results

European Journal of Engineering Education Vol.1(4), 1976, 269-75

The British system of higher education in engineering has used a pre-existing framework of institutions (the universities) to which engineering studies have been added. The advantage of this situation is that existing universities provide a ready-made framework for managing and expanding the teaching of new subjects, with standards of academic quality assured. The disadvantage has been that a university environment favours the advancement of knowledge rather than practice. In engineering, where the link between scholarship and its application should be direct, the term 'engineering science' has been coined as a descriptive title for the activity which is actually pursued.

BAYER, H. and LAWRENCE, P.A. 123

Engineering education and the status of industry

European Journal of Engineering Education Vol.2(3), 1977, 223-27

The standing of industry and of industrial employment is higher in W. Germany than in Britain, and this fact has implications for the recruitment of engineers and students of other subjects related to eventual industrial employment. In Britain all the vocational subjects, except Law and Medicine, are the victims of relative neglect in higher education, where the goal is 'education' and not occupational training. The place of engineering in British higher education is part and parcel of social attitudes towards the purpose of higher education, and the meagre esteem accorded to industry in Britain.

FORD, Sir. H. 124

The professional's dilemma - engineer or ingeneer?

Proceedings of the Institution of Mechanical Engineers Vol.191, 1977, 207-15

For too long engineering has been seen as applied science and both education for engineering and for its practice have suffered from the illusion that it is the scientific culture that has given us all the benefits in our present society. That the engineer is neither of the scientific nor the classical, literary culture, has escaped the notice of most writers. The great engineering developments have preceded, not followed, the elucidation of the scientific principles on which they depended. The essential difference between the engineer and the scientist has to be widely understood if engineers are to correct the misunderstanding about their role.

See also 339.

MACE, J. 125

The 'shortage' of engineers

Higher Education Review Vol.10(1), 1977, 23-41

Despite the disaffection of some the ranks of those crying for more engineers and scientists appear to have swollen. The assertion that there is a 'shortage' of engineers may be based on any one of three models of the relationship between engineering and economic development - the 'manpower-forecasting', 'economic growth' and 'quality of education' models. An examination of these models in relation to educational planning suggests that there is no simple relationship between the allocation of resources to engineering education and the promotion of economic growth.

COLLINS, A.R. 126

The effect of science on the role of the engineer

Proceedings of the Institution of Civil Engineers (Part 1) Vol.64, 1978, 191-205

The development of science during the Industrial Revolution diminished the original role of the engineer as the source of innovation. This was compounded by the division and diffidence of the engineering profession in contrast to the influence exerted by bodies such as the

Royal Society. The idea grew that it was the scientist who was the prime initiator of new technology and that industrial innovation was a progression from pure science through applied research and development to exploitation by industry. As the originator of this process the scientist was seen as the appropriate planner of the national programme of all research. The result was a very high standard of pure science, but also much research which was ineffective and industrially irrelevant.

PROBERT, D. 127

Are changes needed in university engineering courses?

European Journal of Engineering Education Vol.3(2), 1978, 93-115

As late as the 1950s engineering was regarded as a low intellectual calibre discipline in the U.K. In an effort to gain the esteem of other university departments, members of those engineering departments already in existence tended to devise scientifically very rigorous courses with the practical elements severely depleted. Because of this tradition even now many engineering graduates emerge better suited to an academic than to a factory environment. However, recently engineering has risen rapidly in kudos as a subject to be studied, as awareness grows of the economic importance of engineering. Advanced technology and good management are endemic to a progressive society and so their symbiosis in practically-orientated engineering courses is well worthy of being a core activity for U.K. universities.

See also 344.

FINNISTON, Sir M. 128

Engineering Our Future: Report of the Committee of Inquiry into the Engineering Profession, Chairman: Sir M. Finniston (Cmnd.7794, HMSO, 1980, pp.258)

The most significant official study of engineering since 1945 examined the availability, deployment, education, training and professional organisation of engineers within the broad context of national economic needs. The section of the report dealing with education and training adopts the term 'formation' to describe how engineers should be prepared for industry. This is taken to mean an integrated package of academic education and structured training and experience in industry. Undergraduate studies represent one stage in this process, and the Committee proposed two new degree awards, the B.Eng. and M.Eng., for graduate engineers. While the latter is envisaged as a more advanced qualification, both courses are based on the precepts of teaching for economic purpose and of preparing young engineers with the confidence and competence to begin applying their engineering knowledge to real problems.

GLOVER, I.A. 129

Social science, engineering and society

Higher Education Review Vol.12(3), 1980, 27-41

A sociology of engineering should be established, separate from the sociology of science, and with links with the sociologies of industry, occupations, political life and education. Engineering employs a lot of people, directly and indirectly; they are, arguably, the major source of social change; and crosscultural and historical comparison suggest that the knowledge of the status enjoyed by *homo faber* (the maker of artefacts) in a society tells us a good deal about the society's prospects.

See also 233, 624.

LEWIN, D. 130

Engineering philosophy - the third culture?

Journal of the Royal Society of Arts Vol.129, 1981, 653-66

The Two Cultures argument has not only perpetuated the gap between science and the humanities but has also polarised the views of both groups against the world of manufacturing and engineering, which is held to be mundane and devoid of intellectual challenge and creativity. This view has become widely accepted due to a lack of understanding of what constitutes engineering, and to the lack of an identifiable engineering philosophy. As long as engineering is seen simply as a confluence of science and industrial practices, a view still strongly held in schools and universities, engineers will always be considered as second-rate scientists.

See also 354, 441.

WIENER, M.J. 131

English Culture and the Decline of the Industrial Spirit 1850-1980 (Cambridge U.P., 1981, pp.217)

An exploration of the English ambivalence to modern industrial society which reveals a pervasive middle- and upper-class frame of mind hostile to industrialism and economic growth. From the middle of the nineteenth century to the present, this frame of mind shaped a broad spectrum of cultural expression as well as social and economic thought. Thus, élite educational institutions have reflected and propagated an anti-industrial bias. Technological education made slow headway in universities which were an avenue out of, not into, industry. During and after the Second World War the government sponsored the expansion of technical courses but engineering and technology have generally been tolerated rather than assimilated in universities. Long-standing attitudes have eroded the hoped-for effects of more recent educational reform and expansion, as provision for technological education outran demand. For a variety of causes an industrial career has been less esteemed in this country than elsewhere, and this has also affected the development of technological education.

AHLSTRÖM, G. 132

Engineers and Industrial Growth (Croom Helm, 1982, pp.118)

A study of higher technical education and the engineering profession during the nineteenth and early twentieth centuries in England, France, Germany and Sweden. The reasons for the slow development of higher technical education in England are to be found in the limited demand for engineers by industry, the limited career openings for engineers, the development of the engineering profession, and the low standing of an education and career in engineering. That there was no united national engineering organisation serving the interests of engineers had unfortunate consequences with regard to the important supervision of the technical qualifications of engineers. The failure of governments to promote an organised and state-supported technical education, at all levels, must be seen against the background of social factors established in a long-standing class society.

CHISHOLM, A.W.J. 133

Some problems of Government financing of university engineering education in Britain

European Journal of Engineering Education Vol.7(3), 1982, 271-88

The arrangements which exist for managing engineering education and training in Britain have not yet produced influential and informed sources of advice on which those taking decisions about the future of the universities can rely when considering the future of engineering education. There is little tradition for taking advice on this crucial issue from the engineering institutions, the industrial employers' organisations or from the Engineering Professors' Conference. Within the UGC the Technology Sub-Committee has had little scope to influence substantially the development of engineering in the university system; it has had no relevant formal research support to inform the allocation of resources.

See also 550.

CHISHOLM, A.W.J. 134

Government financing of university engineering education in Britain (Pt.1)

International Journal of Mechanical Engineering Education Vol.10(2), 1982, 121-27

British universities, being ultimately autonomous and responsible for managing themselves, have to allocate their resources internally. All British universities are multi-faculty institutions and decisions on resource allocation inevitably have to be made against a background of heterogeneous opinions, attitudes and values. Some members of other disciplines appreciate the practical importance of engineering and the needs of engineering education, others do not; the idea that universities ought not to be concerned with vocational training is still widespread. Thus, in some universities competition for resources is not between science and engineering on the one hand and arts subjects on the other. Competition may be between engineering and science, as some regard engineering as intrinsically inferior to pure science.

CHISHOLM, A.W.J. 135

Government financing of university engineering education in Britain (Pt.2)

International Journal of Mechanical Engineering Education Vol.10(3), 1982, 185-94

British university engineering departments established since the mid 19th century have absorbed the culture of other academic subjects and the ethos set by the ancient universities, resulting in the teaching of a body of knowledge rather than professional skills. This reflected the struggle by engineering to establish itself as an academic discipline within multi-faculty universities. These departments remain strongly science-orientated, and the engineering education provided is still based for the most part on the combination of mathematics and experimental method which was established in the 19th century.

See also 549, 736.

WHITE, J.B. 136

The enhancement of civil engineering education

Future Needs in Civil Engineering Education (Institute of Civil Engineers, 1982), 43-47

In the universities, engineering seems to have been seen as an applied science rather than as a form of professional education. Typically a School of Engineering was added to Schools of Physics, Chemistry, etc. which already existed within a Faculty of Science. Hence courses in engineering have structures closely resembling courses in Physics and Chemistry, and the criteria for the appointment and promotion of staff are much the same as in the pure sciences. The professional bodies should persuade the universities that there are essential differences between engineering and the pure sciences and that engineering schools need to develop their own criteria for both course content and style, and for the recruitment and promotion of staff.

See also 357, 446.

CORFIELD, Sir K. 137

The making of an engineer

Journal of the Royal Society of Arts Vol.121, 1983, 390-401

The partnership of engineering and science is wholly desirable, but that they have tended to be regarded as interchangeable is regrettable. As long as the misunderstanding persists in the minds of opinion-formers and policy-makers, the solution of the most critical problem of wealth creation and employment will evade us. The output of science and research exceeds our ability or will to produce. But whenever large expenditures by government are contemplated the emphasis is on research. Inadequate attention is given to the huge problem of funding and resourcing the resultant product for production. Although the SRC has become the SERC the stigma of engineering as a dependent function persists. If engineering is to be accorded its proper place in the economy, justified by its potential contribution to wealth creation and employment, it should be accorded the distinction of a separate existence.

See also 235, 737.

MILLER, K. 138

The role of the Engineering Council

The Structural Engineer Vol.61A(10), 1983, 306-08

In many other industrialised nations, notably W. Germany, Japan and the USA, engineering has always been recognised as the key activity in the economy. The importance of engineering is implicit in the way of life of those countries; it is not so in the U.K. for historical reasons. During the latter part of the nineteenth century this country began to take for granted the wealth generated by the Industrial Revolution. The schools of the time in effect equated civilisation with the classics. Even pure science was frowned upon, let alone the teaching of the use of scientific principles to solve practical problems. The legacy of this attitude is still with us, and it is one of the main tasks of the Engineering Council to correct it, and to encourage an awareness of what the Finniston Report called the 'engineering dimension'.

See also 739.

PRICE, G. 139

State centralism and the 'alternative road' in higher technical education, 1930-1980

in *The Alternative Road* ed. D. Layton (University of Leeds, 1984)

Since 1945 the major decisions in policy for advanced technical education have been taken during periods of anxiety over Great Britain's economic performance. By the time of the Robbins Report education was seen in planning terms as an investment in the skills needed for economic growth. The co-option of the CATs into the university sector demonstrated that the academic status of technology in the university had been accepted; the campaign for an 'alternative road' in higher education, dating from the Percy Report of 1945, had achieved some success. Subsequent developments, however, show that there is a recurrent and unresolved conflict about the universities' role in technological education which has been made more problematical with growing uncertainties about the validity of traditional economic goals.

2. THE RELATIONSHIP BETWEEN ENGINEERING AND THE SCIENCES

In the competition for political and popular recognition, and in their pursuit of resources, engineers have frequently sought to demonstrate the distinctive nature of their work - to explain that there are important differences between what scientists do and what engineers do. The majority of writers are at pains to stress these differences and to show how engineering activity, if not superior, then is at least on a par with science in terms of the intellectual demands it makes on its students and practitioners. Some go further and argue for a 'Third Culture' dominated by engineering-type activity, separate from both science and the arts. This culture is based on the application of knowledge, scientific and otherwise, to 'useful' ends, and involves the process of designing and producing artefacts to fulfil perceived needs. Hitherto, the educational neglect of this Third Culture can be held responsible for many of the shortcomings of manufacturing industry in Britain. In the late 1950s and the 1960s, at a time of expansion in higher education, there were calls for the significance and independence of engineering, or what some called 'technology', to be given practical expression in the creation of technological universities along the lines of those established elsewhere in Europe and in North America. This idea was not without its critics, who argued for the essential unity of science and engineering. However, over the period as a whole, the increasingly dominant voice is undoubtedly that which argues for engineering to be seen as an independent community with its own philosophy which transcends the notion of 'applied science'.

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MORRIS, C.R. 201

The universities and technology

Universities Quarterly Vol.6(2), 1952, 119-24

In the past technology may have appeared very everyday, practical, and unscientific, but it has been invaded by scientific methods and standards; undergraduate teaching in the technological subjects hardly yields to the pure sciences in its insistence on education in 'fundamental' principles. The advance of scientific knowledge, pure and applied, is indivisible. The universities must attempt to achieve a balance not only between the sciences and humanities (as they generally have done) but also between the sciences and the newer technological subjects.

MORRIS, Sir P. 202

The higher education of scientists and technologists

Universities Quarterly Vol.8(3), 1954, 276-90

The protagonists for technological universities have argued that technological studies will not receive the amount of attention, concentrated effort and freedom to develop in the existing comprehensive universities which they would receive in a centralised university institution dedicated to technology. Although there is some force in this argument, there would be serious consequences if anything was done which diminished the fruitful interaction between on the one hand the pure and applied sciences, and between both of them and other fields of study on the other. The excessive segregation of specialities defeats its own ends, and there is wisdom and safety in not departing too far or abruptly from the tradition of multi-purpose institutions.

See also 307.

OLD, C.L. 203

Engineering

in P.F.R. Venables, *Technical Education* (G. Bell and Sons, 1955), 245-80

Despite the demarcation within engineering there is a general body of principles, practices and attitudes which marks engineers from those who follow other professions, although some may not be exclusively applicable to engineering. Engineering is much more than a science, it is an art in which judgements based on knowledge and experience are bound to play a vital part. Moreover, because engineering practice is based on team-work, there are few other professions in which human relations are so important in determining the quality and quantity of work performed.

M'EWEN, E. 204

Training of engineers

The Engineer Vol.208, 1959, 223

It is essential for the budding engineer to grasp that engineering is more of an art than a science, not least the art of compromise. The problems are not capable of unique correct solutions by the application of basic principles. There must be a balance between manufacturing, service and design considerations, material and tooling availability, and straight commercial and economic aspects. Industry has to make these judgements and it is there only that the technique can be learned.

See also 506, 702.

CLAUSEN, H. 205

The borderland between science and engineering

The Engineer Vol.211, 1961, 896-98

Scientists and engineers differ largely in terms of thought. The former's main concern is with theory and principles leaving the embodiment of these to others; usually he does not care to venture beyond the verbal or the symbolic. The engineer, although equally aware of the importance of principles, is mainly concerned with their embodiment in design before hardware is made; the verbal and the symbolic are his raw materials. The science and the art are in practice mutually supporting, and progress demands the full development of both, at an equal level of human and intellectual ability.

See also 103, 405.

de MALHERBE, M.C. and OPPENHEIM, A.K. 206

Changing structure of engineering education

The Engineer Vol.212, 1961, 1025-28

The most prominent aspect of the problems of engineering education is the controversy between science and engineering and thus the difference between them must be understood. Science implies a body of knowledge and a scientist is one who professes to a part of this knowledge; he seeks to solve problems which have definite answers. The goal of the engineer is to utilise the knowledge of the physical world for social benefit. The problems he tries to solve have many possible answers from which he must select an appropriate solution. The scientist's problem is to discover truth, the engineer's to determine a course of action.

See also 407.

EDGEWORTH JOHNSTONE, R. 207

Some thoughts on engineering education

Nature Vol. 193, 1962, 618-22

Three separate but related activities can be identified: 'pure science', which is the study and investigation of natural phenomena; 'technology', the study and investigation of industrial processes; and 'engineering', the design,construction and management of plant and machinery. In reality the three activities tend to shade into one another, but it is a mistake to confuse them. The study of a natural or industrial process is a different activity from engineering. In particular, the distinction between technology and engineering should not be obscured; if it is,this has the further result of obscuring the real relationship between engineering and science. An engineer makes use of science but his aims lie outside science and he has to submit to disciplines and pressures to which science as such is a stranger.

See also 606, 705.

MAUNDER, L. 208

Dynamics and the Engineer

University of Newcastle-upon-Tyne, Inaugural Lecture, 1962

Unlike the pure scientists the engineer is concerned with the construction and operation of physical systems of his own design. His work is subject to a very wide range of influences from economic, social, medical, legal and other sources, as well as from scientific principles. It is therefore not surprising that the engineering community is so wide, nor that its internal relations are so variable.

See also 409.

ALLANSON, J.T. 209

Engineering in the university

Education Vol.121, 1963, 1045-48

The essence of engineering is that engineers make things to meet the needs of society and individuals. It is a creative activity and the engineer must make an engineering unity of the physical and social sciences. The route to engineering through pure science is not generally very useful, and thus engineering education needs to be more broadly based. Indeed, engineering ought to be attractive to those who dislike the black-and-white character of science and are more excited by questions to which there are many answers, of varying degrees of validity, so that personal judgement may be exercised.

See also 706.

SARGENT, R.W.H. 210

Chemical Engineering and Engineering Science

Imperial College of Science and Technology, Inaugural Lecture, 1963

An engineer is an applied scientist. It follows, therefore, that he has a fundamentally different objective from that of the pure scientist, which can be taken as the quest for knowledge for its own sake. The engineer's objective is essentially social in nature;

he is involved in assuring a service, or making a product, or in providing the means to these ends. Thus, whereas the pure scientist's research is open-ended, the engineer always has a specific objective to attain; he must always keep in mind the project as a whole and each problem must be considered in its context.

See also 411.

BOSWORTH, G.S. 211

Education and training of engineers: what do engineers do?

The Engineer Vol.217, 1964, 927

The main groups of functions performed by engineers indicates not only that each requires a different body of knowledge, but also that it makes different demands on the man's personal attributes. These four groups of functions are: a) commercial; b) design and engineering; c) research and development; d) manufacturing. The specific duties of any post which an engineer may fill will be compounded of one or more of these functions, in different proportions, but one will usually be dominant. Management has not been included in the groups of functions, since this is an activity which permeates all these functions.

See also 412, 510.

SLANN, P.A. 212

Design and the undergraduate engineering curriculum

Conference on the Teaching of Engineering Design (Institution of Engineering Designers, 1964), 181-90

The tasks of engineer and scientist are essentially different. The scientist is a specialist who proceeds to great depth in his chosen field of study, along a narrow front. His main function is the formulation of theories and of methods. The engineer is a decision maker whose decisions are only viable if firmly based on a depth of understanding of science and mathematics and on a broad but not superficial understanding of several disciplines, both technical and non-technical.

See also 414.

OLD, C.L. 213

Engineers for a technological society

Proceedings of the Institution of Mechanical Engineers Vol.179(1), 1964-65, 1071-76

Engineering is somewhat between a science and an art subject. If studying art subjects helps the individual to make value judgements then engineering is as much an art as a science. Even in its scientific aspect it is never as rigid as the science of the physicists. Compromises are constantly forced on the designer who may be considered the technological counterpart of the physicist. The rigid scientist will not make a good engineer as so much of the engineer's decision taking is somewhat arbitrary and so often it has to do with people.

LINSTEAD, Sir P. 214

Science and technology - separate or together?

The School Science Review Vol.46, 1965, 281-93

There is a close and vital connection between science and technology and between scientists and technologists. They share the same methodology and much of the same outlook. In education the first choice between science and technology should be delayed at least until the age of entry into higher education; movements towards the massive teaching of engineering science at school should be resisted. In terms of organisation there should be technological universities specialising in teaching and research in applied science and engineering at the highest level, but with the resources to engage in teaching and research in science and the Social Sciences as well. They will be limited and insufficient instruments of higher education if they confine themselves strictly to the study of technology or engineering. Science and technology should be kept together at the research and educational level; the best division would come at the stage of application where development should link with production.

See also 107.

GERSTL, J.E. and HUTTON, S.P. 215

Engineers : The Anatomy of a Profession (Tavistock, 1966, pp.229)

There are distinctive differences between science and engineering, which must be appreciated. Science is concerned essentially with knowledge for its own sake and with the search for truth. In contrast, although scientific techniques and the knowledge obtained from scientific research are valuable tools in engineering, its object is quite different. Engineering is concerned with creating devices that will be useful; that will, in most cases, sell at an economic price. The translation of modern scientific discoveries into economic wealth is technically in the hands of engineers. Although science and engineering are interdependent, and must remain so, the engineer always approaches his task with a practical objective in mind and with a philosophy different from that of the scientists.

See also 108, 710.

CHERRY, C. 216

The educational values of technology

Schools Council Project Technology Bulletin Vol.2(9), 1969, 99-102

Science alone is not enough in the teaching of Technology. This teaches only the logic of technology and nothing of the premises to which that logic applies, and nothing at all of the ends to which it is directed. The teaching of Technology, of design of artefacts, as though it was the study of things, or 'applied science', based upon specifications and criteria whose origins and purpose are rarely mentioned is not merely amoral but immoral and therefore of poor educational value. Technology should be treated as a humanity, involving not only physics and mathematics but an understanding of traditional 'subjects' such as history, geography and economics. It can be a means of finding meaningful relations between what have hitherto been regarded as separate disciplines. Technology is about human relations and relations with the material world.

See also 111.

WALLACE, P.J. 217

Is the engineer undervalued by society?

The Engineer Vol.229, 18 September 1969, 52-3

There is unbroken continuity between the functions of scientist, engineer, technician, or mechanic, such that it is impossible to identify even approximate points of demarcation; certainly none that could be recognised by society. Science and engineering alike would be impossible without systematic use of the scientific method. Thus up to a point no logical case can be made for separating the engineer from the scientist in relation to society. The engineers' view that their work imposes social responsibilities not exercised by the scientists, who is concerned with the coordination rather than the application of knowledge, is open to question. Today few engineers are responsible for decisions affecting the subsequent commercial exploitation of technical initiatives, as the vast majority are employed by non-engineers in control of the engineering enterprise.

See also 114, 417.

FLOWERS, Sir B. 218

Engineering and the U.K. Science Research Council

Proceedings of the Institution of Electrical Engineers Vol.117(6), 1970, 1192-1200

In its application of the results of scientific and technological advance to social needs, engineering must engage the most serious attention as an integral element in any advanced society. Its practice is technical and inventive, but it is not just these; it is an art embodying the deepest consideration of human, aesthetic, environmental, economic and social factors of the most immediate concern. Thus, while the elements of engineering science and the associated technologies can be separately identified and developed as academic disciplines, the products of engineering industry depend upon a broader, more inter-disciplinary appreciation.

See also 115.

FORES, M.J. 219

Science v. Engineering

New Scientist 8 Jan. 1970, 58-59

The major cultural gap in British society is the one between 'pure' and 'applied', reflected in the long-standing neglect of applied subjects in the educational system. In particular the universities are too much obsessed with an engineering education in analysis rather than in synthesis. Whereas the main definitive concept in science is 'knowledge', in engineering there are two such concepts - 'skill' and 'utility'. Engineering is about the synthesis of knowledge in order to make things and perform industrious functions. The main product of the engineering synthesist is a set of useful, three-dimensional objects which cannot be expressed directly on paper.

See also 416.

FORES, M.J. 220

Engineering and the British economic problem

Quest No. 22, Autumn 1972, 21-23

It is misleading to consider manpower problems in Britain in terms of 'QSEs' (Qualified Scientists and Engineers). A significantly higher percentage of the British stock of graduates in science and engineering are scientists by background compared with the situation is most of Europe. A need for more engineers in industry has often been observed but a recommendation has usually been phrased as a call for more QSEs. Working scientists have been confused with working engineers, resulting in a significant piece of mis-specification.

See also 117, 715.

GREGORY, M.S. 221

History and Development of Engineering (Longman, 1972, pp.190)

Engineering has grown along with fundamental natural science. In earlier centuries engineering problems sometimes stimulated scientific inquiry. But science has also, from the first,pursued its own topics unrelated to the engineering of the times, which have nevertheless produced results with a revolutionary impact on engineering. Today the stimulation seems to be largely from science to engineering. Scientific research has enabled the development of new materials, methods and processes,the challenges of which have been taken up by engineers. However, engineering feats such as space exploration have in turn stimulated scientists in their work, so much so that in certain areas the traditional distinctions between the scientist who seeks for knowledge and the engineer who gets the job done are tending to be blurred.

MOTZ, H. 222

Innovation and the Academic Engineer

University of Oxford, Inaugural Lecture, 1973

Engineering is not applied physics. The whole concept of applied physics is a lingering platonic idea, according to which the pure subject, physics, exists in the world of ideals which can then be applied to more mundane purposes. The basic knowledge needed for 'conceiving material devices for human needs' (i.e. engineering) is the science of devices, which does not fall into the categories of heat, light, sound and electricity. This is because human needs can often be satisfied by different technological means, involving different branches of physics, and also because any one device may involve the different branches in a different way.

See also 424.

BAKER, Sir J. 223

The engineer and survival

Advancement of Science New Issue No.2, 2 September 1976, 2-6

Whatever his speciality, the engineer's activity is also varied, so there is scope for interest and talent however it develops, from innovation and design, through fabrication, production and management, including that most human activity industrial relations, finance and sales.

The engineer is all the time engaged in a real enterprise, to produce something new, within tight limits of cost - something which will work. That it must work, provides the stark discipline but also the immense satisfaction in engineering activity. Thus, the demands, intellectual and in every other way, of the engineer's work are of a higher order than those facing the scientist.

See also 121, 719.

GLOVER, I.A. 224

Engineers - the forgotten profession?

The Chemical Engineer January 1976, 42-44

The aims of engineering and science differ fundamentally. Natural scientists aim to understand and describe the natural, whereas engineers aim to make the artificial. If the central activity of science is research, that of engineering is design. Engineers do not think or act like scientists. In science there is always the hope that there will be a 'best solution', but there can never be in engineering. Every assessment of the value of a technical solution to a problem can only be subjective and temporary. Unlike science, engineering cannot aim primarily at objectivity; it is essentially a completely open-ended activity much more like art than science.

See also 619, 720.

BREWER, R.I. 225

Science and Engineering Education Policy : The Work of Willis Jackson, Baron Jackson of Burnley (1904-1970)

M.Sc. Thesis, U.M.I.S.T., 1978

Jackson frequently referred to the impact of science on technology or engineering (terms he thought were interchangeable). But he also emphasised that the relationship was one of mutual interaction and inter-dependence. His constant theme was that it was only through the mediation of engineering and technology that science had any important effect on the economy. He defined the purpose of engineering as 'the conception and defining of an objective, the harnessing of all the scientific, technical, economic and human resources for purposes of attaining it through design and production, and of ensuring its subsequent efficient and reliable application to the needs of the community.'

See also 534.

FORES, M.J. 226

A proper use of science

in *Manufacturing and Management* eds. M. Fores and I. Glover (HMSO, 1978), 141-55

The phrase 'applied science' implies that the engineer at work is close to the physicist or the chemist. In reality he rarely is, since much of his effort has completely different aims from those of the natural scientist. Similarly, 'science' as one side of a 'two cultures' gap breaks down very quickly as a useful and consistent idea. Some commentators, Snow included, have classed engineering and 'technology' as part of the 'science' side of the gap. But evidence suggests that the engineer and the natural scientist do not act and respond alike: one is concerned with making things, the other with observing things. Therefore, they are not part of the same cultural group.

See also 433.

LAWRENCE, P.A. 227

The engineer and society

Energy World May 1978, 12-14

The two cultures idea of arts versus science does not exist in Germany. All formal knowledge subjects, whether arts, natural science or social science, are classified as *Wissenschaft*. The term *Technik* denotes the knowledge and skills relevant to the production of useful artefacts, that is to say, engineering and technical knowledge and craft skills. Since arts and science are not distinguished in the structural way they are in Britain, science is less likely to be glorified at the expense of engineering. Given the idea of *Technik* as an independent entity, Germans cannot label engineering as 'applied science', which in English usage tends to give it a junior and dependent status.

See also 726.

MUIR-WOOD, A.M. 228

Presidential address 1977

Proceedings of the Institution of Civil Engineers (Part 1) Vol.64, (1978), 1-23

Few people outside the profession understand the central importance of quality in engineering. While engineers make much use of the quantitative sciences their ultimate objectives principally require judgement, foresight and imagination. Snow missed completely the realisation of the central position of the engineer between the superficially opposed world of arts and science. Engineering excellence does not mean technical perfection, but the ability, within the available options, to provide the most appropriate engineering solution, having concern for those who produce, operate and are affected by the project.

See also 622, 728.

CARMICHAEL, W.F. 229

The nature of civil engineering as a profession

Proceedings of the Institution of Civil Engineers (Part 1) Vol.66, (1979), 49-74

Although science and engineering share certain common characteristics there are two important distinctions between the disciplines. The primary aim of science is to explain systematically and completely the natural world as it is. Engineering is an application rather than explanation since it aims to create a useful product. Engineers use scientific explanations to redirect nature. The pursuit of science, and also art, for its own sake is sometimes denounced as irresponsible or even immoral. In engineering there is no such division; the pursuit of engineering knowledge is totally related to a practical purpose which is paramount. Knowledge need not be complete and needs only to be true approximately because the engineer's main test is that of practical achievement; in science knowledge is continually being tested intellectually and experimentally against falseness.

See also 435.

FORES, M.J. and REY, L. 230

Technik : the relevance of a missing concept

Higher Education Review Vol.11(2), 1979, 43-57

Technik, a missing concept in English, represents a separate cultural area, distinct from science and the arts. *Technik* produces what is thought to be useful at any one time by a particular group in their own culture, and is itself a major determining influence on that culture. Engineers are the most important group of exponents of *Technik*. Engineering is *Technik* because its principal working aim is to make and operate useful artefacts, and is, thus, part of a separate cultural area with codes of behaviour, responses and a dignity of its own. Engineering is not 'applied science', which is itself a very suspect notion.

LAWRENCE, P.A. 231

Engineering and the national context

Electronics and Power Vol.25(5), 1979, 359-61

'Applied Science' is a label which both demeans engineering and leads to a misapprehension of engineering work. The West German concept of *Technik* represents a rubric, independent of both arts and science, which both distinguishes and dignifies engineering. The term implies a different relationship between engineering and science, with engineering as a more than equal partner.

See also 730.

LEWIN, D. 232

On the place of design in engineering

Design Studies Vol.1(2), 1979, 113-17

Engineering has its own distinct philosophy, closely related to Popper's philosophy of scientific method, and hence can be considered as a discipline in its own right. Engineering philosophy is based on deductive problem solving akin to Popper's logic of scientific discovery. Though engineering is based on scientific facts and principles, the traditional Baconian philosophy of science and its inductive methods are not appropriate to engineering. To continue to educate engineering students along these principles, and to consider engineering as 'applied science' while the Baconian philosophy prevails, will have a detrimental effect on engineering practice.

See also 436, 540.

GLOVER, I.A. 233

Social science, engineering and society

Higher Education Review Vol.12(3), 1980, 27-41

Social science has manifested the deep-rooted British distaste for manufacturing, by misunderstanding, and indeed, largely failing to examine the content and nature of engineering work. Almost all social scientists have shown a disproportionate interest in 'innovation' and in the interface between science and manufacturing, rather than in manufacturing itself. By misclassifying engineering as part of 'science' in spite of

evidence to the contrary, they have devalued the work of those who design, make and sell goods. Social Science, therefore, has neglected *homo faber*, the maker of artefacts, engineer or toolmaker.

See also 129, 624.

NADLER, G. 234

Introduction to basic engineering concepts: for all students

Bulletin of Science, Technology and Society Vol.2, 1982, 191-204

Engineering is the conversion of theories, information and knowledge into useful results. Engineering is typically considered by both practitioner and general public to concern only highly specific theories and sophisticated machines and products which are 'hard science' based. This damages both the education of engineers and the perception and use of engineering talent. Engineering concerns the whole 'system' of equipment, artefacts, workers, managers and organised operations. Engineering practice usually addresses four types of problem: improve an existing system; diagnose some trouble to find the cause; develop a new system; develop new uses for an existing system.

See also 445.

CORFIELD, Sir K. 235

The making of an engineer

Journal of the Royal Society of Arts Vol.131, 1983, 390-401

Engineering and science are not analogous nor may engineering be properly regarded as applied science. The product of science is knowledge, the product of engineering is normally a three-dimensional artefact. Many engineering achievements precede scientific understanding of the principles on which they depend. Engineering is, of course, made better by the application of knowledge derived from scientific investigation and this has led to the invention of the descriptive word technology. But engineering does not necessarily wait upon science. Engineering is *making* things, and some of the finest engineers have demonstrated an ability which far surpassed that which could have been explained in terms of the application of scientific knowledge.

See also 137, 737.

3. THE ENGINEERING CURRICULUM IN HIGHER EDUCATION : AIMS AND OBJECTIVES

If engineering is seen as 'more than applied science' this is bound to have implications for the education of professional engineers. Engineering emerges from the literature as a problem-solving activity which requires a combination of skills, knowledge and attitudes which cannot be developed by a narrowly based science-dominated curriculum. Because engineering is directly affected by social and commercial factors, the education of engineers themselves needs to be more broadly based than has been the case in the past. In its search for academic status engineering gradually shed from its curricula the more practical elements, and concentrated on the teaching of fundamental science, particularly physics, and mathematics. The protagonists for a broader education have sought to reverse this trend in two ways. First, by introducing into the curriculum studies of the social and commercial context within which engineers operate in the real world. Thus, we see below repeated calls for undergraduate engineers to be made aware of the nature of engineering activity and to be taught how to cope with the non-technical factors which are an integral part of the planning, design and implementation of engineering projects. The other main theme is an emphasis on the formulation of answers to engineering problems through synthesis rather than analysis. The analytical approach, fostered by an overtly scientific curriculum, is seen by many as inappropriate to engineering which is essentially a synthetic process, and, it is argued, this basic fact should be recognised in the way engineers are educated.

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KASTNER, L.J. 301

Education, Tasks and Outlook of the Engineer

University College Swansea, Inaugural Lecture, 1950

A technical education in engineering must rest upon a foundation of mathematics. The standard required may not be an exalted one but it is essential that the engineer should be able to employ with confidence the rather low-brow mathematics which suffices for the vast majority of practical problems. Engineering mathematics is a principal skill of the engineering scientist, and must be sufficiently well developed to ensure his professional competence.

See also 101, 501, 601.

TUSTIN, A. 302

Broader education in a department of applied science

Universities Quarterly Vol.4(3), 1950, 266-74

Applied science graduates are too often deficient in breadth of knowledge, in strength of interests, in social awareness, in maturity and stability of personality and in sensitivity and the understanding of people. In the Department of Electrical Engineering at Birmingham University some simple innovations have been made with the object of stimulating the personal development of students and broadening their interests. These innovations centre round the introduction of periods of an hour each week throughout the course for group discussion on general topics. Associated with this is the writing of essays and the provision of a small library of books on economics, education, psychology and other non-professional subjects. After three years discussion groups appear to be successful and effective as a form of broader education.

MUCKLOW, G.F. 303

The universities and the education of the engineer

Proceedings of the Institution of Mechanical Engineers Vol.164, 1951, 396-98

Although the principles of engineering are universal and eternal, and the work of the undergraduate should be related closely to the fundamental sciences, it is important that the engineering attitude of mind should be preserved in both student and teacher. The engineer essentially 'visualises' and the engineering student is often unable to stomach an overdose of the abstract concepts which would be digested happily by the student of pure science. To the engineer science and mathematics are but a means to an end.

See also 503.

CULLWICK, E.G. 304

Engineering education and the universities

Research Vol.5, 1952, 297-303

Numerous official reports issued since 1945, together with international comparisons, reveal the need for a revision of engineering education and training in Britain. Hitherto the universities have made changes in engineering curricula which are piecemeal and superficial rather than fundamental, as the situation demands. They should introduce two types of course to provide the main body of engineers and a smaller group of 'engineer-scientists'. The former would follow a three year course, comprising fundamental science, engineering science and the humanities, in preparation for practical training and industrial employment. The second group would follow a course lasting 4 or 5 years, to allow for more advanced study in pure science and mathematics. The graduate from this 'applied science' course would require a shorter period of industrial training.

PYE, Sir D. 305

The art of the practical engineer

Engineering Vol.174, 1952, 542-44

The aim of the engineer is essentially positive: to devise and construct something that is better for its purpose than that which has existed before. In too many engineering courses, however, too little attempt is made to develop more than one side of an engineering student's work - the analytical and mathematical one. Not enough opportunities are provided to encourage the potential engineering designer or manager. Too much emphasis is placed on the somewhat sterile pursuit of solving artificial problems in engineering, invented for examination purposes.

See also 401.

BAKER, J. 306

Opening address, session on higher technological education

Report of the Proceedings of the 7th Congress of the Universities of the Commonwealth 1953 (The Association of Universities of the British Commonwealth, 1954), 161-66

A distinction should be made between the technician (who deals with today's problems and is a master of accepted techniques and processes) and the technologist (who will deal with tomorrow's problems and who can improve old methods and invent new ones). In the past universities

have attempted to produce engineers who were effectively technicians, whereas they should have the task of producing technologists. The technologist's education should be based on a grounding in the whole range of engineering science, presented essentially by engineers, with their own philosophy.

MORRIS, Sir P. 307

The higher education of scientists and technologists

Universities Quarterly Vol.8(3), 1954, 276-90

A distinction can and should be made between a scientific and a technological education. The former is one in which the student is required to submit to the logical and systematic development of his subject as a branch of knowledge where the end in view is the mastery of principle and the relevance of the subject to other fields of systematic study. A technological education concerns itself with the acquisition of knowledge for the purpose of achieving industrial or commercial objectives, and the acquisition of skills and techniques, important as it is to the mastery of the necessary knowledge, is also of vital importance to the industrial or commercial objective in view.

See also 202.

BURSTALL, A.F. 308

Methods of teaching mechanical engineering subjects at British universities

Proceedings of the Institution of Mechanical Engineers Vol.171, 1957, 463-68

The framework of university courses in mechanical engineering has suffered little change during the last fifty years. There have been many minor changes but these are not commensurate with the progress that has taken place in the practice of mechanical engineering during the same period. Most academic engineers are conservative in outlook and have yet to become accustomed to a philosophy of perpetual change in their teaching work; indeed the majority are apt to resist it. At present there is too much emphasis in university courses on fundamental science and too little on creative engineering.

See also 404.

EVANS, Sir I. 309

The place of engineering in university education

Proceedings of the Institution of Mechanical Engineers Vol.171, 1957, 1025-30

It is a mistake to see the study of engineering as solely the study of technical expertness and of a professional practice. Engineering is a discipline as good as any other and better than some. Engineering courses at universities should be broadly based on first principles or fundamentals to constitute a full and very exacting university discipline. It would be short-sighted to introduce current practice at the undergraduate level; this would submit to the short-term requirements of industry, instead of the long-term policy of engineering development as a whole.

FRANCIS, A.J. 310

Engineering education and engineering practice

The Engineer Vol.211, 1961, 848-52

In the English speaking world there has been over the last fifty years a gradual movement in engineering curricula away from the teaching of practical applications and towards greater emphasis on pure and applied science. This is an inevitable and laudable development. There has been great expansion in the theoretical basis of engineering, but no increase in the duration of courses, and the basic material has gradually squeezed out the treatment of engineering practice. Courses today are far superior as a mental discipline to those of the past but one must ask whether it is the kind of mental discipline most appropriate to a creative profession. There is a great danger in the present emphasis on the analytical approach that it may inhibit and stultify the creative instinct of the engineering student.

See also 406.

HASELDEN, G.G. 311

Chemical Engineering and Its Educational Challenge

University of Leeds, Inaugural Lecture, 1961

An ideal course in chemical engineering must satisfy at least three criteria. It must challenge the student to think deeply by avoiding an unrelieved diet of theory. Only when the significance of the theoretical approach in solving practical problems is appreciated will lively interest in theory be awakened. To prepare the student for tomorrow's problems as well as today's the underlying science must be emphasised rather than the present empirical solution. The powers of leadership and communication within the student must be encouraged in preparation for the functions of coordination and management which ultimately he will be required to fulfil.

PARKES, E.W. 312

The Education of an Engineer

University of Leicester, Inaugural Lecture, 1961

It is not the function of a university engineering department to produce engineers: that is something which industry can do much more satisfactorily. Its function is to educate people, bearing in mind the kind of lives they are going to live. The engineer requires an education which provides a general understanding of the principles which are common to all forms of engineering - especially design, production and management - without giving him detailed factual knowledge which he can immediately apply to particular industrial problems. It should provide the essential background rather than the real substance of engineering. The young engineer must receive the rest of his education and training from industry, because what remains is most economically and satisfactorily taught there.

See also 408, 605.

THRING, M.W. 313

The role of the universities in teaching technology

Advancement of Science Vol.17(69), 1961, 456-60

Engineering is the attempt to provide accurate design formulae based on appropriate empirical measurements, while Applied Science is the attempt to provide rough-and-ready design formulae based on fundamental principles. The Engineering approach is essential if one is to improve the factors of safety in design, and the Applied Science approach is essential if one is to strike out into new fields where empirical formulae are not available. The two processes are thus supplementary, and the universities' role in teaching technology is to provide a good grounding in both Engineering and Applied Science and ensure that students understand fully the relation of industrial processes to fundamental science.

KING, A. 314

Life-long education of the engineer

Engineering Vol. 194, 1962, 9-9

The fact that modern engineers have longer working lives than in the past, together with the increasingly rapid rate at which scientific advance is being exploited technologically, suggests that the knowledge obtained by an engineer during his traditional education is insufficient to last him the whole of his career. In the future the first and most serious stage of formal education prior to productive employment should provide for life a precise intellectual discipline, the capacity to make decisions and, above all, the will and ability to learn. The engineer's professional credentials will need to be renewed periodically by later training.

LINSTEAD, Sir P. 315

Presidential address

The School Science Review Vol.43, 1962, 310-19

The formal education of engineers in universities is steadily moving towards becoming an education in engineering sciences as students spend an increasing amount of time learning the fundamental principles of their subjects. This trend has been encouraged by the growth of postgraduate training in specialised topics which relieves the pressure on the undergraduate curriculum resulting from new developments and inventions. But the young engineer should not only have as fundamental, but as liberal, an education as possible. This could be achieved by more spill-over of specialist work into postgraduate courses and a more liberal treatment of technological material in the first degree course.

BOSWORTH, G.S. 316

Education and training of engineers: getting to the root of the problem

The Engineer Vol.217, 1964, 986-87

Engineering is an art as well as a science. But the teaching of its art does not fit comfortably into the universities which are the traditional home of scholarship. The typical university pattern of education is a satisfactory preparation for those engaged in research and development, but the education and training of men for design and manufacturing

functions is not adequately served by existing courses. These functions are essentially creative, whereas the emphasis in current education lies in analysis. The problem is to devise a training route for those engaged in the technology of engineering to replace the former arduous and prolonged 'evening classes' route. This must be based on a clear distinction between engineering science and engineering technology; the latter goes beyond the areas fully explored by the scientist and also relies on observatons, inferences and an empirical as well as an analytical approach. This is the essence of the creative art of engineering.

HUMPHREY DAVIES, H.W. 317

The design and control revolution

Proceedings of the Institution of Electrical Engineers Vol.112(1), 1965, 127-36

University courses in engineering start with three main themes: mathematics, engineering science and engineering method. Ultimately these are replaced by courses aiming at the professional requirements of different branches of engineering. At present this arrangement tends to detract from the major objective of supplying competent engineers capable of conceiving, planning, producing and operating significant engineering systems. The basic themes of engineering studies should be extended from three to four: mathematics, materials science and engineering, engineering science and practice, engineering design and planning.

LACEY, P.M.C. 318

The Chemical Engineer and Society

University of Exeter, Inaugural Lecture, 1965

There are broadly two kinds of chemical engineering courses: those which are 'science orientated' and those which are more closely related to industrial operations in practice. At present there is a trend away from the science orientated course, but there is a case for its superiority. Instead of responding to pressures from industry, where the thinking is on a relatively short-term basis, universities should teach their students the fundamental knowledge they will need to draw on throughout their careers. In later years they will find it difficult to learn in this way, divorced from the grip of current practice.

COLE, B.N. 319

Mechanical Engineering 1975

University of Leeds, Inaugural Lecture, 1967

However pure other disciplines may be, and however much their followers take satisfaction in their purity, engineering in its very nature is multiple in character, wide-raning in scope. Within the framework of a truly broad education the novice mechanical engineer needs special ability in physics and mathematics. Possibly developments in 'new' materials will restore chemistry to a more important role as a foundation subject, but the position of the other two subjects will remain indefinitely central and secure.

See also 415.

GAMBLING, W.A. 320

Electronics in Transition

University of Southampton, Inaugural Lecture, 1968

Although fundamental studies in mathematics and physics are essential for the engineer universities must beware of producing quasi-scientists with no knowledge of, or sympathy for, real engineering. An engineering course must seek to achieve six main objectives: to provide a sound knowledge of relevant scientific principles; to develop a critical and inventive approach to problem solving; to develop the capacity for independent learning; to provide some knowledge of current engineering practice; to introduce students to the sociological implications of engineering, and to develop the character of the individual student.

See also 416.

BALDWIN, C.T. 321

Industry, university and engineers

Proceedings of the Institution of Electrical Engineers Vol.117(3), 1970, 661-63

It is of primary importance that the engineering student is taught fundamentals, but his interest and enthusiasm must be stimulated by the sense that he is dealing with real engineering problems in his studies. As long as undergraduate courses are limited to three years duration the various 'subjects' of engineering courses cannot be treated as separate disciplines; the course must be conceived of as an entity of closely interrelated parts. Specialisation is properly the function of post-graduate training directed towards industrial engineering activities.

See also 512.

DIAMOND, J. 322

University engineering education 1960-1980

Advancement of Science Vol.27(132), 1970, 164-70

The task of the university engineering teacher is more complex than that of the pure scientist. In most cases the latter can gear his methods and values to the end-point of research as the highest and best manifestation of his calling. In engineering a university course is only part of a student's education for work in which research normally occupies only a very small part, and which depends for its successful accomplishment on many skills that can be learned best in industry.

See also 612.

FRANCIS, D.C. 323

An Investigation into the Mathematical Education of Engineers

M.Sc. Thesis, Loughborough, 1970

Examines problems associated with maths courses for students of engineering. Concludes that maths courses should be relevant to the modern advances in the applications of mathematics to engineering, and they should aim to interest the student and provide a sound understanding of basic structure upon which a student can build knowledge of techniques relevant to his particular specialism. Although maths courses for engineers are changing, too little time is devoted to statistics and numerical methods. Maths should appear as the supremely logical language in which real problems may be formulated and their solutions obtained.

HINTON, Lord 324

Engineers and Engineering (Oxford U.P., 1970, pp.75)

Too often industry finds that the engineers with the greatest creative ability are those who came up the technician-engineers' ladder by means of a craft apprenticeship and part-time study. One can ask, therefore, whether creative ability is being crushed out of young people by the volume and complexity of the theory that is now taught in university courses. The first degree course should aim to give the thorough knowledge of mathematics and physics that underlies all engineering theory and should teach the student how to apply this to a variety of practical engineering problems. The mental exercise given in university training should seek to develop the power that will enable young engineers to solve the kind of problems they meet in industry.

See also 419, 515, 614.

KERENSKY, O.A. 325

Fuller education and training of engineers

The Engineer in the Community (Institution of Civil Engineers, 1970), 8-14

It is not feasible or even desirable to produce, during the normal university education period, engineers with really expert knowledge of the many specialised branches, and this part of education is probably best left to postgraduate training and continuous further self-education. Chartered engineers must first of all be generally educated men. The actual curriculum of subjects studied is less important than the training in creative and logical thinking, analysis and presentation of conclusions, combined with the art of self-expression and leadership, which can be defined as decision-making and creating the conditions in which others can carry-out those decisions.

See also 615.

BROWN, J. 326

Universities and technology

Proceedings of the Institution of Electrical Engineers Vol.118(1), 1971, 9-15

It is a reasonable assumption that the majority of undergraduate engineering students have committed themselves to a professional career in engineering. Accepting this assumption implies that the main objective of the undergraduate course is to develop the capacity of the students to obtain realistic solutions to engineering problems. Realistic solutions require an awareness of social and economic considerations as well as purely technical ones. There is no 'best' course which is universally applicable because the makeup of a satisfactory course will be affected by factors such as the quality of the student intake, staffing, resources and collaboration with local industry.

CHARLTON, T.M. 327

The development of engineering education

The Aberdeen University Review Vol. 44 (4), 1972, 331-38

Specialisation has increasingly become a feature in undergraduate engineering courses. So long as great care is taken to emphasise the scientific concepts which are common to various branches of engineering science and to avoid material which is purely technological and subject

to rapid change, there would appear to be no harm in a measure of specialisation in the later stages of undergraduate courses. Ultimately the objective is to lay the foundations for a career as a professional engineer able 'to deal with circumstances for which there is no direct precedent'. Then it is for the profession, in practice and in industry, to complete the process by providing the experience and engendering attitudes which only they can do to provide themselves with useful people.

See also 116.

GORDON, D.S. 328

Passport to a profession

Proceedings of the Institution of Electrical Engineers Vol.119(3), 1972, 385-86

An engineering course should have several objectives. It should give basic instruction in mathematical techniques relevant to engineering calculations. A good appreciation of the underlying fundamental scientific principles is also necessary. These form the foundations of the discipline of engineering, but they do not constitute the discipline. Students should be aided in developing an enquiring and critical mind, and facility in oral and written expression. Their education should also create an awareness that engineering is not a cold analytical science but a humane discipline in which social and ethical obligations are inescapable.

See also 422.

OLD, C.L. 329

The United Kingdom concept of the complete engineer

The Training of Professional Engineers (Federation Europeanne D'Associations Nationales D'Ingenieurs/Institution of Civil Engineers, 1972), 123-29

Engineering educators and trainers in the U.K. believe profoundly that technology alone is not enough for a chartered engineer. A major role of the Council of Engineering Institutions is to ensure that all such engineers are educated and trained beyond the relatively narrow confines of a traditional degree course. The unique contribution of the U.K. to the training of engineers is the concept that engineering is much bigger than engineering science.

WALKER, V. 330

A new look at course content

Tomorrow's Engineers: Proceedings of a Conference held at Bradford University ed. B. Wood (University of Bradford, 1972), 2-7

It is now widely recognised that with the growth in output of engineering graduates, a growing proportion will enter occupations which are somewhat peripheral to engineering. Engineering courses therefore have to fill not only a vocational function, but also to serve as a general education. Courses can be designed to foster intellectual development; to provide a sound foundation in relevant areas of science and mathematics; to develop creativity, communication skills, team-work; and to create an awareness of the economic and management factors which affect engineering practice.

See also 521.

TAILBY, S.R. 331

Chemical engineering education today

Chemistry and Industry 20 January 1973, 77-85

The function of the university is not primarily to teach people how to do a job but to train minds and give a grounding in fundamentals which will not change and which can be applied throughout a career. The long term and short term aspects of a course must be continually kept in balance. An emphasis on the latest techniques and technology at the expense of fundamental scientific knowledge should be avoided, although, equally, a degree course in chemical engineering science should not be so theoretical that it resembles a course in mathematical physics and produces graduates whose knowledge is irrelevant in industry.

INSTITUTION OF CIVIL ENGINEERS 332

Report of the Chilver Committee on the Education and Training of Civil Engineers (Institution of Civil Engineers, 1975, pp.71)

An examination of the broad requirements of education and training of civil engineers, including first degree studies at universities and polytechnics. It is recommended that these courses should be broader, although there is need to maintain the appropriate depth of study in a limited number of relevant subjects. The Institution should exercise more control over first degree courses by reviews at regular intervals. The main purpose of these courses is to provide a student with a basis for scientific thinking, and for continuing learning of scientific principles and their application to creative engineering achievement. However, more attention should be given to improving the art and practice of communication, at present a weakness among engineers. The present length of first degree courses is acceptable, provided they are properly structured.

RODWELL, C. 333

Design can and is being taught but...

Engineering Vol.215, 1975, 718-20

Engineering comprises the complex activities which put a product on the market or capital plant into operation. The professional engineer brings the fundamental and practical enabling skills needed to a wide spectrum of these activities, especially feasibility, design, manufacture or production, erection, commissioning, operation and maintenance. The common basis of professionalism he brings to these areas is his understanding of mathematics and engineering science, together with his knowledge of the application of this theory. While he will benefit from a knowledge of management, finance and marketing, if he is not competent in these areas, someone else will attend to them. But if he is deficient in engineering science no one in the average business is able to notice this incompetence or make up for it.

See also 428.

TOPPING, J. 334

Sandwich courses

Physics Education Vol.10, 1975, 141-43

More important than content in university engineering courses is the avoidance of over-crowded syllabuses, the teaching methods used, the nature of laboratory work and the use of students' experience in

industry. A compromise has to be reached between breadth and depth; one is forced to accept that teaching and study in depth are essential but only possible over a limited range, and that this cannot include all the latest developments in spite of the clamours of specialists. If students have been educated and not merely taught they will have the skill to acquire other skills and new knowledge, a more important acquisition than additional factual knowledge.

See also 526.

BISSELL, P.N. 335

Industrial contracts: their effect on the teaching of mechanical engineers

European Journal of Engineering Education Vol.1(2), 1976, 126-30

Until recently many engineering departments had developed courses which were predominantly a scientific training. But an engineer is more than a scientist. He is an innovator working with and for people to design and produce the things they need. He must have a thorough grounding in scientific method but his work is often creative rather than analytical. He frequently has to make decisions with incomplete information or conflicting requirements. Accurate analysis is often impossible. It is this difference in outlook which must be reflected in the educational pattern of engineers.

See also 429.

THOMPSON, J.R. 336

The professional engineer in the 1990s

Proceedings of the Institution of Electrical Engineers Vol.123(1), 1976, 101-106

Engineers must play their full part in developing suitable flexible organisations capable of transforming the impacts of technology into systems for healthy growth. They could act as the interface between technology, economics, organisation and politics, if engineering education ceased to concentrate on technological subjects, almost to the exclusion of the humanities. The basic first-degree course should be devoted to a broad spectrum of engineering, with specialisation and the broader humanities subjects introduced at the Master's degree level.

See also 721.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE 337

Education, Engineers and Manufacturing Industry

(University of Aston, 1977, pp.59)

Significant changes in engineering course curricula have been made during the past ten years. The traditional engineering course which aimed to shape all students in the same mould is rapidly becoming the exception. Notable developments are the broadening of courses to include economics and management subjects, increased flexibility through providing multiple options in technical and non-technical subjects, and a sharpened interest in design as a vehicle for integrating basic subjects. These developments are healthy because they enable universities and polytechnics to cater better for the varied interests, abilities and capacities of students, and for the wide range of industry's needs.

See also 531, 722.

FISHWICK, W. 338

The engineering professor's dilemma

Impact of Science on Society Vol.27(4), 1977, 369-77

In a first degree course the engineering student learns mathematical techniques, engineering science and the state of the art in his chosen speciality. He learns to assess experimental evidence but is seldom asked to discuss the effects of a particular technology in terms of its socio-environmental impact. Yet this is an essential component of an engineer's training. He should be encouraged to judge and then form his own opinions, expressing these as effectively as he can. Making judgements about his studies and about the effects of future technology on society has not been expected of the engineer as it has of the arts or social science student.

See also 430, 620, 723.

FORD, Sir H. 339

The professional's dilemma - engineer or ingeneer?

Proceedings of the Institution of Mechanical Engineers Vol.191, 1977, 207-15

Professional engineering is essentially decision taking in the creation of artefacts fit for their purpose to meet the perceived need at an acceptable price in a competitive market against a background of incomplete knowledge and uncertain boundary conditions with scarce resources of materials, men and money. Engineering education has therefore to satisfy a triple role. It has to develop the abilities and attitudes needed for influencing decision-taking at all levels. It has to develop those abilities that are needed for realising products. It has to develop those powers of understanding and of working closely with those who will have to produce and sell the products.

See also 124.

GRAYSON, L.P. 340

The Design of Engineering Curricula (UNESCO, Paris, 1977, pp.131)

Descriptions of the engineering educational systems in various countries (including the U.K.) are provided in order to illustrate the variety of philosophical and institutional structures within which curricula must be designed. The book also presents a generalised approach to curriculum design felt to be of value to people in many countries, operating under a variety of social, economic and organisational arrangements. The methodology consists of three stages: problem definition, which requires developing an information base, identifying the need for engineers, and setting goals for the curriculum; structuring the curriculum, which includes selecting and organising the content and teaching approaches to be used, with consideration given to the resources and constraints that exist; and the implementation and evaluation of the final curriculum. The methodology should be viewed as a model for a process to be followed, rather than a receipe for curriculum design. Too many variations exist among nations to permit a fixed formula to be followed.

LANDON GOODMAN, L. 341

The status of engineers and engineering

Engineering, Technology and Society: Proceedings of Section X, British Association for the Advancement of Science, Lancaster 1976 (University of Aston, 1977), 111-15

Undergraduate courses in engineering are, in general, highly specialised and many are highly mathematical, research orientated, based mainly upon analysis, and there is little synthesis and assessment in the teaching. Yet engineering is about the identification of problems, putting them in order of priority and knowing how best to solve them; this requires a different education than that devoted to analysis. The present type of education causes a screening effect, so that young people with a desire to have a career such as that given by law or medicine are turned away instinctively from entering an engineering course. There is, therefore, a need to provide for very well qualified students, degree courses in engineering which are far less specialised and mathematically based.

See also 724.

BENSON, F.A. 342

The growth of electronics and its implications for education

Proceedings of the Institution of Electrical Engineers Vol.125(1), 1978, 75-80

The history of developments in the electrical manufacturing industry since the late 19th century is paralleled by that of electrical engineering education. The Second World War resulted in a virtual explosion of the electrical/electronics industry. The undergraduate engineering curricula began to increase emphasis on fundamental science aspects of electrical engineering, particularly physics and mathematics, by reducing the time devoted to teaching engineering practice and cutting out subjects that were of little concern to electrical engineers, such as surveying etc. There has been some reaction against this and today there is difficulty in finding time in 3-year courses to include all the analytical and practical teaching that a graduate may need. There is an inevitable pressure resulting from this, and from the advancement of science and technology, for longer university courses in engineering and for more students to undertake postgraduate studies.

BROWN, G. and MATLEY, W. 343

Engineering training through practice as well as theory

European Journal of Engineering Education Vol.3(1), 1978, 43-54

High level engineering practice is critically dependent on a sound knowledge of scientific principles but equally important to an engineering career is the acquisition of practical skills. Traditional university courses set the greatest importance on the natural progression and assimilation of academic, theoretical skills which are readily examinable. They play down construction, manufacture and measurement skills, which are so essential for practising engineers. One must always realise that theoretical engineers do not exist. Eventually any engineer must satisfactorily answer the question 'Does it work?' Universities can provide an integrated course in engineering which combines the development of fundamental and technical knowledge with the attainment of practical skills.

See also 533.

PROBERT, D. 344

Are changes needed in university engineering courses?

European Journal of Engineering Education Vol.3(2), 1978, 93-115

Some of the commonest criticisms emanating from industry concerning orthodox engineering courses would not arise if courses were designed so that only essential knowledge and basic practical skills for a general engineer are condensed into a two year course. Much of the engineering science contained in first degree courses is irrelevant to the needs of an engineer. Thus, the proposed two year B. Tech. course includes only what is essential, industrially relevant knowledge. A better training would be provided by a comprehension of a few general principles, with a thorough grounding in the way in which they apply to industrial circumstances.

See also 127.

BARNETT, C. 345

Technology, education and industrial and economic strength

Journal of the Royal Society of Arts Vol.127, 1979, 117-30

British education fails to educate for capability in the process of designing, making and marketing products that people will wish to buy in preference to rival ones, and we are paying the price in chronic lack of industrial success. It is doubtful whether basic social and educational values have yet been adjusted in favour of education for capability, and industrial success as a major goal. Until such educational short-comings are made good, we shall never overcome the pervasive lack of capability, that inferiority of calibre at all levels compared with our rivals, that explain our present want of competitiveness.

See also 729.

BURGESS, T. 346

New ways to learn

Journal of the Royal Society of Arts Vol.127, 1979, 143-57

Educators are presently preoccupied with scientific, formal or philosophical problem-solving, and neglect what can be called engineering or practical problems of the kind which concern most people. This can be seen in engineering education where the route to Chartered Engineer status begins with studies in mathematics and physics at 'O' and 'A' level. It would be preferable if aspiring engineers were faced directly with the problems of engineering. They would find no difficulty in recognising the value of the mathematics and physics they needed and would have the incentive of learning it.

JENKINS, D.E.P. 347

The role of non-technical studies in engineering education in the first years

European Journal of Engineering Education Vol.4(2 & 3), 1979-80, 119-29

The formation and education of engineers is largely defined by the role they play in society. Modern society has four main characteristics relevant to engineering education: increasing complexity; rapid change; the increasing importance of the technological and scientific approach;

a critical attitude towards technology and its realisations. The formation of the engineer should, therefore, consists of: a general intellectual forming; a more specific, though still broad teaching, which generates an interest in technology, natural sciences, and socio-economic sciences; a specific training in a particular discipline; the development of certain attitudes, e.g. management ability, creativity and inventiveness, critical judgement, social and ethical consciousness, initiative and dynamism, leadership and team spirit.

COWAN, J. 348

The basic dichotomy in engineering education

European Journal of Engineering Education Vol.4(4), 1980, 241-53

A fundamental dichotomy confronts anyone who seeks to define the aims of engineering education. On the one hand there are those who stress that there is a hard core of basic knowledge, which must be studied and mastered by any competent engineer. There is an equally valid school of thought which stresses that the engineer should be essentially a creative person, whose creativity is revealed in one particular open-ended professional activity generally known as design. With the first approach the prescribed syllabus will determine the problems to be studied, with the second the initial problems generate the syllabus for detailed simultaneous study. The dichotomy can be solved by combining the strengths of both approaches, and thereby compensating for the weaknesses of both.

See also 437.

FORD, Sir H. 349

Engineering education and the new professional requirements: the educationalist's viewpoint

European Journal of Engineering Education Vol.5(1), 1980, 43-51

In the minds of both government and the public the engineer has long been closely associated with the pure scientist - pure in the sense that the predominant objective has been the advancement of knowledge. The result has been that engineering education has been very closely modelled on that of the scientist. The essential difference of attitude and objective has often been misunderstood and indeed ignored. The engineer is concerned in decision taking, in devising solutions to meet the needs of society within a system of restraints, limitations and resources against a background of people, time, money and the market need. Engineering education has to aim at providing the knowledge, abilities, ways of thinking and the management of skills to meet these requirements.

See also 438, 543.

TOMKINS, R. 350

Educating the engineer for innovative and entrepreneurial activity

European Journal of Engineering Education Vol.5(2), 1980, 97-159

The orientation of some engineering courses is biased towards a scientific or theoretical approach. There is a lack of awareness of practical constraints and a functional narrowness which overlooks the commercial, marketing and manufacturing environment within which engineering is practised in industry. These courses may concentrate too much on

developing the critical faculties which, however,need to be switched off to facilitate any inventive process. Yet the requirement to be innovative is an integral, if not the prime, aspect of professional engineering practice.

See also 440, 545.

DICKENSON, J.F. 351

The future education of professional engineers

Proceedings of the Polytechnics' Engineering Conference (Dept. of Education and Science, 1981), 39-41.

During the 1960s the expansion of university education caused a change in the mode of education of professional engineers and a movement away from the predominantly part-time patterns of the past. There is now an imbalance between theoretically and practically educated professional engineers and an urgent need to restore the balance by the establishment of new degree courses having a more applied engineering content than the traditional university degree course, and characterised by an emphasis on the solution of practical engineering problems.

FORD, Sir H. 352

'Through thick and thin' - the education and training of mechanical engineers

International Journal of Mechanical Engineering Education Vol.9(3), 1981, 189-98

An underlying theme in the development of mechanical engineering at Imperial College since 1945 has been the conviction that an engineering education has characteristics and objectives that are essentially and necessarily different from those of science courses. The introduction of economics, industrial sociology and management studies into the college demonstrates the belief that engineering involves factors other than the technological. The engineer needs to understand industry and the interconnection between men and machines.

See also 546, 625.

INSTITUTION OF ELECTRICAL ENGINEERS 353

Engineering Education and Training National Conference 1980

(Institution of Electrical Engineers, 1981, pp.146)

The papers, debates and recommendations of the National Conference on Engineering Education and Training, 1980. These are grouped around six key themes:

1. Secondary Education
2. Basic formation
3. Accreditation of the formation package
4. Recognition of professional competence
5. Continuing formation and updating of knowledge
6. The technician support base.

The Steering Committee in issuing the Report see it not as another discussion document but specifically a call for action in the wake of the Finniston Inquiry. A principal recommendation is that a four-year degree course should be the normal route to professional engineering status.

LEWIN, D. 354

Engineering philosophy - the third culture?

Journal of the Royal Society of Arts Vol.129, 1981, 653-66

Applied Science is a term which has become synonymous with engineering. But the use of this term with its implied assumption that applied must in some way be inferior to pure science has helped to denigrate engineering. Applied science has exactly the same objective and methodology as pure science. Thus the use of adjectives like applied science or engineering science to describe engineering courses conceals but does not change the fact that these courses are predominantly based on a study of mathematics and physics.

See also 130, 441.

LIFE, E.A. and WILD, R. 355

The development of creative engineers

Oxford Review of Education Vol.7(1), 1981, 3-9

The Brunel University Special Engineering Programme was established as part of the 'development of engineers for industry' strategy. An undergraduate formation 'package' was designed with a broad engineering base, integrated training, experiential activities, exposure to and experience in design, an emphasis upon synthesis and the application of engineering science, and focussing on the creation of 'artefacts'. Psychometric tests have been employed in an attempt to select potentially creative students for this course, with early indications of success. As well as identifying the potential for creativity in engineering this approach emphasises the 'human dimension' in engineering and the inappropriateness of a dependence on a purely scientific approach to engineering problem solving.

ISAAC, P.C.G. 356

The future of university education in civil engineering

Future Needs in Civil Engineering Education (Institution of Civil Engineers, 1982), 49-55

Most teachers of civil engineering equate rigour with the mathematical and physical sciences, which provide the background ('engineering science') for most engineering. There is an implicit (or even explicit) assumption that design, engineering practice etc. can be categorized as rule-of-thumb, and do not require the same mental discipline. This is not true; much analysis can be almost 'automatic' to the mathematically dexterous, while it is always difficult to avoid 'sloppy' thinking, to achieve practical development of ideas.

See also 443, 627.

WHITE, J.B. 357

The enhancement of civil engineering education

Future Needs in Civil Engineering Education (Institution of Civil Engineers, 1982), 43-47

Current university training of engineers emphasises the discipline of fundamental subjects at a pure science level without much special regard for application. In engineering practice the scientific principles have to be used in a different context, in design rather

than in analysis. Filling the gap between science and application, analysis and design, or theory and practice should be the main objective of lengthening degree courses from three to four years. The additional time should be used to ensure that the fundamental sciences are carried through to a stage of design and constructional application, rather than to include more 'theory'.

See also 136, 446.

BEURET, G. and WEBB, A. 358

Engineers - Servants or Saviours? (Goals of Engineering Education Project - GEEP)

(CNAA Development Services Publication No.2, 1983, pp.30)

250 graduate engineers and 200 of their professional colleagues were interviewed to find their views on the abilities and skills which engineers need. The results provide a clear picture of a body of engineers which is technically competent but lacking in most other respects. Their knowledge of the broad business context of engineering and their social and communication skills were heavily criticised both by the engineers and their colleagues. The findings suggest that engineers need a longer, broader and more thoroughly vocational preparation than they now generally receive. A statement of goals in engineering education, concerning technical and personal/intellectual abilities, is provided in an attempt to specify the necessary conditions which should be satisfied by the initial formation of any graduate engineer. At present it could be said that the education which most engineers receive is both technically narrow and narrowly technical.

KING, G. 359

Notes on the evaluation of formation of electrical engineers

International Journal of Mathematical Education in Science and Technology Vol.14(5), 1983, 593-641

The professional engineer must be able to deploy three main skills: mathematical skill (the ability to deploy mathematical knowledge to useful ends); knowledge skill (the ability to evoke appropriate pieces of knowledge from the store to elucidate a problem); techne (an ability to produce useful artefacts). But there is also a fourth dimension to engineering activity - an ability to handle and manipulate whole patterns and changes of pattern through intuition, synthesis and design. In the formation of engineers techne requires attention and educational institutions should consider how it might be given parity with the two 'academic' skills, because it is the primary factor which distinguishes engineering from science.

4. THE PLACE OF DESIGN IN THE ENGINEERING CURRICULUM

The corollary to the concept of engineering as a problem-solving process is to see it as a creative activity also - engineering as an art rather than a science. Design, therefore, plays a major role in the work of the professional engineer as he is required to evaluate alternative 'answers' to a given problem, and to select and develop an optimum policy for implementation. For many of the authors cited below, design is the heart of all engineering activity. The idea that engineering education should place greater emphasis on design was promoted by the Fielden Report in 1963 and by the Moulton Report, published by the Design Council in 1976. Design and synthesising elements have come to assume an increasingly significant role in engineering courses, but the teaching of design poses some unresolved problems. In part these derive from the fact that the design function operates at many levels, from strategic planning down to detailed draughtsmanship, and there appears to be some uncertainty about the kind of design appropriate to the professional engineer. There are also issues relating to how engineering design can be taught and, indeed, whether it can be taught to any great effect in an educational situation divorced from the real-world constraints experienced by the practising designer. More fundamentally some writers, who equate design with creativity, would question whether it can be taught at all.

* * *

PYE, Sir D. 401

The art of the practical engineer

Engineering Vol.174, 1952, 542-44

At present the university atmosphere is not really conducive to creative engineering. The teachers themselves are mainly of an analytical turn of mind, skilled in methods of research but only incidentally interested in new opportunities for design and construction. Yet the university student should be made more aware of the importance of design in the progress of engineering. The present emphasis on analytical and mathematical skills does nothing to foster the creative mind or the 'art of engineering ' - design work which calls in practice rather for the instinctive skill of the artist than the calculations of the mathematician.

See also 305.

M'EWEN, E. 402

The training of engineering designers

The Engineer Vol.195, 1953, 724-25

Insufficient attention is given by universities to the training of designers. The engineer in training gets the idea that genuine engineering problems are of the analytical type and that problems of synthesis are either not engineering or not worthy of the attention of a highly qualified technologist. This must colour his attitude to the designer in industry. Thus, engineering

undergraduates should undertake real design work under the supervision of members of the university staff who themselves practise as consulting engineers; such men should be valued as highly in the universities as the research worker and the mathematical engineer.

M'EWEN, E. 403

Training of engineering designers

The Engineer Vol.198, 1954, 221-23

The tendency nowadays is to produce a race of engineers who cannot draw and to neglect the creative side so that the most able graduates are drawn into other activities. For industry to prosper we must not only pay attention to productivity but to the quality of what is produced: the designer is the key man. His importance should be recognised and he should be more highly rewarded. There should be more stress on design in university engineering curricula, and a recognition that synthesis is not only more difficult but also more generally necessary than analysis. Design ability should be recognised in the degree pass list for engineers.

BURSTALL, A.F. 404

Methods of teaching mechanical engineering subjects at British universities

Proceedings of the Institution of Mechanical Engineers Vol.171, 1957, 463-68

Fundamental science is undoubtedly the foundation of engineering, but it is too often mistaken for the structure, and the results of experiments fail to be translated onto the drawing board or into actual hardware. At present the intellectual disciplines of an engineering course may tend to make a student less instead of more creative. Design work should be regarded by staff and students as the highest form of activity in which a mechanical engineer can engage.

See also 308.

CLAUSEN, H. 405

The borderland between science and engineering

The Engineer Vol.211, 1961, 896-98

Whereas research workers and scientists have a high status in Britain, designers do not. This neglect of design is having serious repercussions on the ability of firms in this country to compete with firms in other countries which accord greater esteem to designers. At present graduate engineers are loathe to work in a drawing-office and this cuts them off from one of the most important sources of learning in their profession: that progression from ideas to hardware on which all else depends. Ultimately, 'a sound grasp of the basic principles' is of little value unless combined with a real ability to apply them in practice.

See also 103, 205.

FRANCIS, A.J. 406

Engineering education and engineering practice

The Engineer Vol.211, 1961, 848-52

More attention should be paid to the development of the creative faculty in engineering students. This is difficult to initiate: it is easier to teach analytically than creatively, scarcely any help can be got from textbooks, and practically all published work adopts an analytical attitude. Another obstacle lies in the fact that many engineering educators are too much out of touch with practice to be effective as instructors in creative design, and there is a need for some teachers to be continuously in closer contact with practice in their own field. What is needed is more than a revision of design courses; the creative attitude needs to be infused into the presentation of lecture courses in other parts of the engineering syllabus.

See also 310.

de MALHERBE, M.C. and OPPENHEIM, A.K. 407

Changing structure of engineering education

The Engineer Vol.212, 1961, 1025-28

To meet the challenge of the technological progress of our times undergraduate engineering education should develop along the following lines: 1. The 'Science of Engineering Design' should be given at least an equal recognition to analytical sciences in the university curriculum for engineers. 2. Subjects should be introduced which foster the 'Science of Engineering Design' and provide a rational background for design. Design should be treated as an indispensable part of the curriculum in order to integrate the analysis and synthesis into a unified methodology for tackling the engineering task.

See also 206.

PARKES, E.W. 408

The Education of an Engineer

University of Leicester, Inaugural Lecture, 1961

Design is one of the functions of the engineer which differentiate him from his fellow scientists, and should form part of a non-specialist engineering education. The designer works not by direct synthesis, but by cumulative experience of analysis. Universities can develop the student's skill in analytical methods but cumulative experience of analysis can only be provided by industry. An undergraduate course cannot provide sufficient experience for the student to attempt real design. Moreover, at present a literature of design is almost non-existent. Engineering education, therefore, can provide the future designer with the analytical basis of design but cannot discuss design itself; this is something which must be learned in industry.

See also 312, 605.

MAUNDER, L. 409

Dynamics and the Engineer

University of Newcastle-upon-Tyne, Inaugural Lecture, 1962

An essential condition of success in engineering is that scientific law and manufacturing skill be combined in response to creative ideas. The engineer must be creative. He must ask how as well as why, and then he must go and do it. If this creative attitude is the hallmark of an engineer, it should obviously be encouraged at Universities and by employers. During a four year curriculum, however, it is much easier to instil an appreciation of the scientific laws of engineering than it is to develop a talent in creative design. Perhaps this is the industrial employer's role?

See also 208.

BOSWORTH, G.S. 410

Towards creative activity in engineering

Universities Quarterly Vol.17(3), 1963, 286-97

The teaching of the science of engineering now dominates the teaching of the art of engineering. In general the university pattern of education is a satisfactory preparation for those engineers who will be engaged in research and development activities but education and training for the design and manufacturing functions are not adequately served by existing courses. These functions are essentially creative, whereas the emphasis in current education lies in analysis. New types of courses need to be developed to redress the present imbalance in engineering education and produce graduates with academic training and practical experience.

See also 105.

SARGENT, R.W.H. 411

Chemical Engineering and Engineering Science

Imperial College of Science and Technology, Inaugural Lecture, 1963

Design is the most typical engineering activity and provides a unifying theme for engineering education. An honours engineering course should be built around a central theme which gradually unfolds the successive stages in design, developing the engineering viewpoint, pointing out the specific requirements, and indicating the foundations on which it all rests. Conversely the basic courses and supporting subjects should be constantly related back to this central theme, with appropriate treatment of detail in the various ramifications.

See also 210.

BOSWORTH, G.S. 412

Education and training of engineers: what do engineers do?

The Engineer Vol.217, 1964, 927

Engineering courses are, in the main, analytic in character and are more concerned with an understanding of phenomena rather than the art of applying this understanding to useful ends in the field of design and manufacture. These courses best prepare men for, and excite their

interest in, research or development, and as a result the other functions become progressively denuded of able recruits. They have declined in public esteem, and two of the most important sectors of our national effort are losing their drive.

See also 211, 510.

CHISHOLM, A.W.J., and GREEN, H.N. 413

Teaching of design in undergraduate integrated courses

Conference on the Teaching of Engineering Design (Institution of Engineering Designers, 1964), 157-80

The study of engineering design by undergraduates has an educational value in its own right, apart from meeting the need to educate and train more engineers who will practise professionally as design engineers. Design introduces the student to the essential quality of an engineer - the capacity to create, through the application of scientific knowledge to practical problems, the use of judgement and the act of decision making. Students can be made aware of the essential differences between the pure scientist and the engineer. The results of engineering design studies become more meaningful with greater knowledge of engineering science, manufacturing processes and real design situations. The sandwich course has a vital role to play in providing this knowledge and experience.

SLANN, P.A. 414

Design and the undergraduate engineering curriculum

Conference on the Teaching of Engineering Design (Institution of Engineering Designers, 1964), 181-90

Design is common ground to both scientists and engineer. It is the liberation of human intellect from the constraint of analysing only the consequences of established formulae, and the access to the discovery of new and unsuspected concepts - which only abstract and logical thought can achieve. It is only from this viewpoint that design can form a legitimate part of the university undergraduate curriculum.

See also 212.

COLE, B.N. 415

Mechanical Engineering 1975

University of Leeds, Inaugural Lecture, 1967

At the University of Leeds one of the most important individual courses in Mechanical Engineering - which is largely served by the rest - is that of design for manufacture. For some years this type of course has tended widely to be the poor relation in the family of subjects. At Leeds an industrial design and manufacture scheme is operated whereby students actually produce machines and pieces of apparatus to a given design specification. This sort of positive and constructive scheme invigorates the design function as nothing else can, and is obviously superior to the traditional design project started and finished on the same piece of paper.

See also 319.

GAMBLING, W.A. 416

Electronics in Transition

University of Southampton, Inaugural Lecture, 1968

Engineering, at its highest level, is a process of invention and innovation. It is not too much of an exaggeration to say that pure science is concerned with analysis, the breaking down of the complex processes of nature into their simplest elements, whereas engineering is a synthesis of a wide range of complex facts and factors into a greater structure which, hopefully, is of benefit to mankind. It is essentially, therefore, a creative experience, in which current practice must be continually questioned.

See also 320.

WALLACE, P.J. 417

Is the engineer undervalued by society?

The Engineer Vol.229, 18 September 1969, 52-3

The intellectual snobbery of engineers has rebounded to the detriment of the entire profession because the policy of denigration automatically relegated design (the heart and origin of all engineering) to the professional dog-house in company with the despised 'mechanics'. Design has been superseded by science, and the engineer by the scientist in the public mind because of the position adopted by engineers. They have been guilty of thinking too much about society and not enough about the essentials of engineering, especially design.

See also 114, 217.

FORES, M.J. 418

Science v. engineering

New Scientist 8 January 1970, 58-59

Design is the main engineering activity. Without good design manufacturing, marketing and management will fail. Design is the central process intervening between the intention to make something and the end-product - a useful object. (In science the parallel activity is research, linking the intention to discover something with the end-product - knowledge.) However, the universities still neglect to teach design to engineering students and misguidedly continue with an education based on analysis rather than synthesis and design.

See also 219.

HINTON, Lord 419

Engineers and Engineering (Oxford U.P., 1970, pp.75)

Engineering is not a science: it is an art. Design is the highest form of the engineering art. Many university schools of engineering are now attempting to teach design in their undergraduate courses but it is doubtful whether they can do much more than teach the principles that are involved. The art of design is to arrive on the drawing-board at the best compromise between conflicting requirements and considerations; information on these matters flows into the design office from research,

sales, manufacturing and other departments. These conditions cannot be artificially reproduced in a university, and thus real design can be taught only within industry.

See also 324, 515, 614.

BROWN, A. 420

The education of professional mechanical engineers

Proceedings of the Institution of Mechanical Engineers Vol.185, 1970-71, 621-24

The art of engineering is design in its broadest sense. Design is engineering commonsense: the what, when and where of engineering. Formal education and training can do much more in the art of engineering than is the case at present. In the later years of engineering courses much more freedom must be given to students so that they can acquire experience in the art of engineering, via real problems, with guidance from both academic and practising engineers. The emphasis needs to be removed from formal examinations and placed on design in these years. Design is creative and all design problems - real engineering problems - are open-ended and demand free-thinking.

See also 516.

FALKLAND, J. 421

Engineering designer

Project No.20, Autumn 1972, 2-6, 36

In its general sense design is the recognition of a basic need and the creation of a system to satisfy that need. The designer, therefore, is constantly seeking alternative ways of solving each problem and having found or created a number of such alternatives, then evaluates each in order to select the most appropriate solution. The selected solution is then elaborated or developed until the optimum product is produced in terms of performance, cost, appearance and time. The designer must learn to think logically, with method, and creatively. However, mere abstract thought is insufficient. It is necessary for the designer to experience personally the manipulation of the materials and processes of the engineering profession. Thus, practical engineering training and academic study are the parallel paths which lead to a career as a trained and competent engineering designer.

GORDON, D.S. 422

Passport to a profession

Proceedings of the Institution of Electrical Engineers Vol.119(3), 1972, 385-86

In a society expecting more material goods and better services innovation and design ability are the skills required by many engineers. A greater proportion of engineering graduates should be orientated towards such careers. The great majority would be concerned with production, design and development, this leading in many cases to management. These graduates would be better prepared by more general degree courses supplemented by suitable postgraduate education and training facilities.

See also 328.

GREGORY, S.A. (ed.) 423

Creativity and Innovation in Engineering (Butterworths, 1972, pp.313)

Based on the papers presented to a symposium on 'Creativity and Engineering' held at Aston University in 1970. An examination of critical issues which are complex and interrelated. To provide a basis for future discussions and action the principal facts and opinions regarding four major aspects of creativity and innovation in engineering and technology have been brought together in the 18 papers from educationalists and industrialists:

1. The nature of creativity and innovation and how they can be studied and measured.
2. Possible ways of improving technological creativity by way of the educational system at secondary and higher levels.
3. Ways used in practice which are believed to stimulate creative performance.
4. The relationship between economic growth, national living standards, and creativity and innovation - leading to the statement of needs for managerial action.

MOTZ, H. 424

Innovation and the Academic Engineer

University of Oxford, Inaugural Lecture, 1973

Technical universities on the continent teach students how to carry out specific engineering tasks, such as design. Our three year undergraduate course cannot fulfil this function, nor should it. On the one hand in the lifetime of an engineer technology is likely to change radically, and a broad educational foundation will make him more adaptable to the inevitable changes. Moreover, it is recognised that a man can be over-trained, that he will almost never be able to use all the detailed skill in designing specialised equipment in his later career.

See also 222.

LAYTON, E.T. 425

Technology as knowledge

Technology and Culture Vol.15(1), 1974, 31-41

Technology may be viewed as a spectrum, with ideas at one end and techniques and things at the other, with design as a middle term. Technological ideas must be translated into designs, to be implemented by techniques and tools to produce things. Thus, design - an adaptation of means to some preconceived end - is the central purpose of technology. In the case of 'ordinary engineering' known means are adapted to a given end; in the case of invention or innovation, one or more of the components in the design may be new, familiar components may be used in a new design or a new design may utilise new components. Whatever the type of design, 'ability to design' represents the engineer's crucial test of technological ability.

See also 120.

BLACK, J. and BRADFORD, D. 426

Making design teaching effective at undergraduate level

Engineering Vol. 215, 1975, 972-76

Engineering design presents a specific educational challenge in terms of objectives and methodology. The design element of any degree course cannot be planned in isolation from the overall concept or structure. The failure of previous attempts to introduce design teaching has frequently arisen from the misguided grafting-on of a new activity to a conventional course. The integrated sandwich course in engineering provided at the University of Bath is an attempt to meet these problems. Design teaching is included throughout the four years and assessment of the students' work in the second, third and final years contributes to the final award.

FRENCH, M.J. 427

Integrate it - don't add it on

Engineering Vol.215, 1975, 826-27

Rather than isolate design as a separate topic in first-degree engineering, what is needed is design-oriented or design-conscious teaching applied throughout such courses. Design is only one aspect of engineering, but it is more central than analysis which at present dominates the curriculum. The engineering department at Lancaster University tries to redress the balance, at least to the extent of stimulating any latent design talent rather than repressing it. Two particular areas still seem unsatisfactory - the infusion of design into engineering science topics is not yet adequate, and students are still not really introduced to the importance and subtlety of detail design.

RODWELL, C. 428

Design can and is being taught but...

Engineering Vol.215, 1975, 718-20

Engineering science must dominate the undergraduate course because this knowledge cannot be picked up in later life as experience can in the various areas of practice. However, the engineer's job is to apply existing knowledge and his training must be biased towards this. It is necessary, and possible, to develop the student's design skills. The core of design activity is actually designing, and students must develop the ability to conceive and represent on paper every detail. In this they can be helped only by practice, i.e. project work. To improve this method of learning should be the aim of developments in design education over the next few years.

See also 333.

BISSELL, P.N. 429

Industrial contracts: their effect on the teaching of mechanical engineers

European Journal of Engineering Education Vol.1(2), 1976, 126-30

Much of the education of an engineer takes place through his work. The object of a university course in design must be to accelerate his development. It should not attempt to do those things which will inevitably and more appropriately be done in industry. It should

nurture an interest in solving open-ended problems; it should give students the opportunity to make mistakes, which are an important part of the design learning process, and to learn to tolerate criticism and to gain confidence. It is for those aspects of the engineer's education that design projects can be most effective.

See also 335.

FISHWICK, W. 430

The engineering professor's dilemma

Impact of Science on Society Vol.27(4), 1977, 369-77

Engineering educators must know what engineers do in industry and act on this knowledge. Most engineers (including those concerned with production, construction and maintenance) carry out design work: 40 per cent of the engineers in industry are primarily design engineers. Hence engineering courses must pay considerable attention to the kinds of design process and experimental investigation likely to be encountered in practice. For the engineering student, thorough knowledge of one design method is a better introduction to design than a superficial knowledge of many.

See also 338, 620, 723.

HEYWOOD, J. and MONK, J.D. 431

The education and career patterns of professional mechanical engineers in design and management

Vocational Aspect Vol.29(72), 1977, 5-16

The complexities of the modern firm have relegated the design function to one section of a complicated system. The declining importance of engineering design is reflected in the departure from the design office of talented and ambitious engineers. Professional engineers see the management function as the route to career advancement in terms of greater responsibility and higher salaries. Design education can and should develop the relationship between design and management, by highlighting managerial aspects of the design function, e.g. problem solving techniques, spatial abilities, and computer programming for C.A.D.

See also 621.

NEVILLE, A.M. 432

Education of professional engineers in Britain and on the Continent

Civil Engineering Education and Training 1976 (Institution of Civil Engineers, 1977), 1-10

To teach engineering is to teach analysis and synthesis; design is the end of all study of engineering. Not only is design a fundamental engineering activity, but in learning design the engineering student gains confidence and learns to tolerate criticism. The alternative to design projects in the undergraduate's education is to seek refuge in analysis where the student engineer's efforts have a more predictable outcome and where failure is less visible. Analysis does not equip students to deal with open-ended problems or to design simple pieces of equipment.

FORES, M.J. 433

A proper use of science

in *Manufacturing and Management* eds. M. Fores and I. Glover (HMSO, 1978), 141-55

There is a highbrow world within both 'cultural groupings' - arts and science - where true creativity is thought to belong to 'us' and not to the 'them' of manufacturing where preoccupations are held to be humdrum and without major challenge. It should be better accepted that flair and creativity are as much in demand in manufacturing as they are in the fine arts or natural science. It is not science but personal skill and creativity which produces invention and innovation in manufacturing.

See also 226.

ARCHER, B. 434

Design as a discipline

Design Studies Vol.1(1), 1979, 17-20

There are not two but three areas in education, the third being an approach to knowledge, and a manner of knowing, which is distinct from those of Science and Humanities. Where Science is the collected body of theoretical knowledge and the Humanities is the collected body of interpretative knowledge the third area - Design - is the collected body of practical knowledge. Thus there exists a designerly way of thinking and communicating that is both different from scientific and scholarly ways of thinking and communicating, and as powerful as scientific and scholarly methods of enquiry, when applied to its own kind of problems, i.e. those derived from man's concern with the appreciation and adaptation of his surroundings.

CARMICHAEL, W.F. 435

The nature of civil engineering as a profession

Proceedings of the Institution of Civil Engineers (Part 1) Vol.66, 1979, 49-74

Scientific theory and techniques will vary during the career span of an engineer, whereas attitudes of mind inculcated at an early stage do not. Engineering education should pay particular attention to methods of identifying the core of a problem, judging priorities, forming a model for analysis and appreciation of the finished product. For the civil engineer design means more than dimensioning a beam: it means querying whether one is required, considering alternative structure systems and integrating all the other aspects as well as safety. The teaching of design means also setting out the general criteria of how excellence emerges from the competent solutions.

See also 229.

LEWIN, D. 436

On the place of design in engineering

Design Studies Vol.1(2), 1979, 113-17

The primary goal of engineering is the production of artefacts for society, and the design function is the method of achieving this end. Thus, design is the core of engineering and creative innovative design the highest form of engineering endeavour. Design should occupy a

central place in the engineering curriculum, and not be seen as an adjunct to it, as is currently the case. Although it is impossible to teach creativity, students can and should be exposed to design situations to learn by experience.

See also 232, 540.

COHAN, J. 437

The basic dichotomy in engineering education

European Journal of Engineering Education Vol.4(4), 1980, 241-53

The study skills and problem-solving abilities which are essential qualities in a creative engineering designer take some time to develop. They should be nurtured deliberately and specifically, over a sustained period, within the educational environment, and should not be left to develop accidentally and erratically. This implies that at least part of the syllabus should be open-ended. However, teachers of engineering still have a great deal to learn about the best ways to stimulate creativity and to support individualised learning.

See also 348.

FORD, Sir H. 438

Engineering education and the new professional requirements: the educationalist's viewpoint

European Journal of Engineering Education Vol.5(1), 1980, 43-51

The essential feature of engineering decision taking is the ability to synthesise the solution of a problem against incomplete boundary conditions which stretch beyond the technological content, and in all that is taught the underlying consideration should be to inculcate a natural ability to think both analytically and synthetically at the same time. It is undesirable to separate design and production considerations in engineering education. Some of the difficulties encountered in developing good designers arise from this separation; design is the final synthesis and flows through every branch of engineering in one form or another.

See also 349, 543.

HARRIS, A.J. 439

Can design be taught?

Proceedings of the Institution of Civil Engineers (Part 1) Vol.68, 1980, 409-16

The education of civil engineers is directed to excellence in construction. Design is the determination of what is to be built and the preparation of the instructions necessary for building it; it is central to excellence in construction and thus to the education of the civil engineer. Design must not become a soft option; by integrating into design exercises the science which students are learning concurrently, these can be made intellectually demanding. Engineering education is the development of intellectual faculties; the faculty of design is important and should be taught. Both science and art are dialogues between two voices, the imaginative and the critical. Both voices are needed but imagination is the more excellent and should be fostered.

TOMKINS, R. 440

Educating the engineer for innovative and entrepreneurial activity

European Journal of Engineering Education Vol.5(2), 1980, 97-159

Industry's needs are for a large number of engineers to take a creative and leading role in innovative engineering and its management, and for a relatively small number of industrial leaders and innovators of the highest level. Such abilities cannot, perhaps, be formally taught, but they can be enhanced and reinforced, principally through the use of active learning methods. Complementary subjects should not merely be added on incrementally to the curriculum but should be integrated with design and project work. This may require a radical rethinking of the approach to teaching, centred around the teaching of design practice and methodology as a unifying theme.

See also 350, 545.

LEWIN, D. 441

Engineering philosophy - the third culture?

Journal of the Royal Society of Arts Vol.129, 1981, 653-66

Design is an integral part of the engineering process and indeed is its central philosophy. Engineering philosophy is based on the principles of deductive problem solving and comprises an amalgam of Popperian logic and general systems theory. This philosophy is fundamentally different from that of the traditional sciences and arts and can be considered a Third Culture. Engineering philosophy could form the core element for a liberal education which would result in uniting the arts and sciences and dispel the view that engineering is an anti-social and academically inferior activity.

See also 130, 354.

MAILLARDET, F.J. 442

'In search of reality': the role of design studies in engineering education

European Journal of Engineering Education Vol.5(4), 1981, 309-18

An engineering design course should equip graduates with the technical and social skills necessary to enable them to tackle a creative piece of engineering design. These skills include: graphical skills, practical skills, communication skills, application skills (so that information from the specialist subject areas can be applied to a real situation), methodological skills (so that a logical, systematic approach may be made to the design activity), and team skills. Familiarity with some skills may be acquired in isolation from a creative design situation but application, methodological and team skills are very difficult if not impossible to teach from a theoretical standpoint separate from the design situation.

See also 548.

ISAAC, P.C.G. 443

The future of university education in civil engineering

Future Needs in Civil Engineering Education (Institution of Civil Engineers, 1982), 49-55

One of the characteristic functions of engineering is design. It is in design that the engineer tests and applies his theories in meeting a real need. It is an effective means of demonstrating to the undergraduate that he must expect to apply the sophisticated analytical techniques, which he has learnt, to useful ends, and must not regard them as ends in themselves. It also shows that the engineer's technical solutions, to what appear to be technical problems, will always be constrained by men, money and materials. As such, design is an essential vocational element in the undergraduate course.

See also 356, 627.

MORRIS, D. 444

Engineering design and manufacture

Engineering Design Education Spring 1982, 25-29

The department of Engineering Design and Manufacture at the University of Hull admitted its first undergraduates in 1981. The department explicitly features engineering design as a central rationalising theme for a four-year degree course linking aspects of engineering science, materials and manufacturing technology together with production management and commercial awareness. Engineering design underlies the entire activity of engineering and manufacture. It is also an ideal vehicle with which to demonstrate the application of classroom-taught analytical methods in engineering science and also the problems involved in material selection and manufacture.

See also 551.

NADLER, G. 445

Introduction to basic engineering concepts: for all students

Bulletin of Science, Technology and Society Vol.2, 1982, 191-204

Planning and design represent one of the major purposes of engineering, but engineering design and problem solving methods are certainly not complete nor universally agreed upon. As processes they draw on a wide range of knowledge: cognitive, human, cultural, behavioural, psychological and organisational as well as technical. Effective solutions depend on only 10 to 20 per cent of technical knowledge and 80 to 90 per cent on other factors. Engineering education can now prepare students who understand the complexity of maximising the effectiveness, innovativeness and creativeness of solutions while maximising the likelihood of implementing them along with maximising the utilization of resources in the solution finding efforts.

See also 234.

WHITE, J.B. 446

The enhancement of civil engineering education

Future Needs in Civil Engineering Education (Institution of Civil Engineers, 1982), 43-47

Good design comes only from the experience of the results of analysis, which students must learn and practise in the early stages of their education. But the experience gained from analysis will rapidly decay if it is not used for design. Even the basic theory will be forgotten and design will be (as it often is) a process of copying and adapting the designs of others with an extreme reluctance, borne of lack of confidence, to do any hard fundamental thinking or to use the best theoretical basis currently available.

See also 136, 357.

CONWAY, H. 447

An engineer's view of design

Journal of the Royal Society of Arts Vol.131, 1983, 454-69

Design is the mechanism by which science and engineering can be put into the service of man. However, given that few engineers are themselves designers, many of them have failed to realize what design is all about, or what a designer really is. There has been an attitude that the creative innovator or designer should think up solutions, leaving it to others to produce the detailed drawings and specifications necessary for successful production. Perhaps there is now a wider acceptance of the equal importance of conception and detail execution, which can only come from team work, blending creative brilliance with less creative, but equally important, skills and experience in producing reliable and saleable products.

FINKELSTEIN, L. 448

Design education of electrical engineers

Engineering Vol.223, 1983, 503

The teaching of engineering science in a design oriented way could be the most effective means of improving design teaching in first-degree courses. The teaching of design should be based on a sound foundation of design principles and knowledge. There should be a design methodology underlying the study of design. Much work needs to be done on the methods of teaching design. Formal teaching, case studies and projects all have a role to play, but perhaps the most powerful method of teaching design is the design-oriented teaching of engineering science. The basis of all engineering education must be a sound foundation in engineering science, but at the same time all engineering teaching should be closely related to applications.

HORNE, M. 449

Academia - the role of the higher education establishments

The Structural Engineer Vol.61A(10),1983, 310-11

Academics have considerable sympathy for the view that graduates need a better bridging experience between the discipline of engineering science and the challenge to deal with real problems that face them when they enter practice. This is indeed the aim of the four year courses

now making a tentative appearance in civil engineering. Although civil engineering courses have generally included more studies in some form of design than has been the case in other engineering disciplines, the restriction to three years has made it difficult to do this adequately. A fourth year would allow a re-organisation of courses to convey an appreciation of economic influences, construction techniques and the approach to project design; thus allowing students to acquire real awareness of their significance and impact in the work of the engineer.

PETTY, E.R. 450

Engineering curricula for encouraging creativity and innovation

European Journal of Engineering Education Vol.8(1), 1983, 29-43

Engineering courses do not generally encourage creativity and innovation. Indeed, having followed a vigorously analytical programme with a heavy and tightly scheduled timetable, graduates are likely to be less creative than when they entered university. The easiest vehicle for remedying this deficiency in creativity is the design project. Other active learning methods (e.g. case study discussion groups, guided design) also provide scope for creativity, innovation and decision-making. These attitudes are engendered by their injection into the range of engineering courses rather than by an isolated course in creativity - and certainly not by a passive lecture course.

SMITH, Sir A. 451

Aesthetics and Engineering (Association for Science Education, n.d.,pp.13)

There is great beauty in good engineering - for those with the insight to see it. Throughout education, we do not seem to get across to young people an appreciation of the subtle and delightful aspects of engineering as well as we get across to them an appreciation of literature or art. The teaching of engineering tends to be a matter of analysis, of setting problems, and of getting the sums right. But a piece of good engineering can give as much aesthetic pleasure as many a work of literature or art. There is also much good engineering in some human achievements of great beauty, as can be seen by examining examples of building and artefacts in history.

5. PRACTICAL TRAINING FOR UNDERGRADUATE ENGINEERS

In discussions about the purpose of engineering education at undergraduate level one question stands out: should it produce graduates with specialist knowledge and skills, conversant with current engineering practice, or with a general technological education which can be adapted to the specific needs of employing organisations through their own training programmes? With the designation of the technological universities in the wake of the Robbins Report, and of the polytechnics in the later 1960s, the growth of sandwich courses was evidence of a trend towards more industrially relevant engineering education. For the most part, the exposure of students to the engineering 'front line' has been accepted as desirable and beneficial in providing a tangible link between education and industry, and a demonstration of the underlying purpose of engineering education. Of late the value of this approach has been called into question and increasingly attention has focussed on the problems it has encountered: the dearth of training places in industrial firms and the poor integration of industrial training with academic studies. Within the universities and polytechnics themselves teaching and learning methods have evolved in response to the pressures for more design education and the development of skills as opposed to the extension of knowledge. Thus, project work has become a significant element in most present-day engineering courses. This is the other main issue discussed below, given that project work represents a further attempt to introduce students to practical engineering activity, albeit on a more limited scale and in a different form from that offered by industrial training.

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KASTNER, L.J. 501

Education, Tasks and Outlook of the Engineer

University College Swansea, Inaugural Lecture, 1950

The training of the engineer must be a blend of the academic and the practical, but in recent years the shift in emphasis from practical to theoretical training has accelerated. The result has been the production of specialists well-suited to the mass production era. But, where adaptability and vision founded on wide experience are required, as they are in the highest posts, a scheme based on apprenticeship might produce the better engineer, more conscious of workshop problems, and the potentialities of men and machines.

See also 101, 301, 601.

MOULLIN, E.B. 502

Inaugural address

Proceedings of the Institution of Electrical Engineers Vol.97(1), 1950, 1-6

Undergraduates learn their electrical science in an academic discipline designed primarily for a wider purpose - to teach them how to continue to learn for themselves in later years. This discipline provides a sound foundation for acquiring professional competence. The professional training of the university graduate, therefore, is based on the profession, in the industry, not in the university.

MUCKLOW, G.F. 503

The universities and the education of the engineer

Proceedings of the Institution of Mechanical Engineers Vol.164, 1951, 396-98

A university course can contribute little to the personal experience and comprehensive knowledge of engineering practice which are essential to the fully qualified engineer. These can be acquired only amid the atmosphere and realities of industrial engineering. The complement to the university course is a systematic practical training, without which the product of the university is likely to remain one-sided. The widened horizon resulting from a two-year apprenticeship serves to bring confidence and perspective to the graduate engineer.

See also 303.

VENABLES, P.F.R. 504

Technical Education (G. Bell and Sons, 1955, pp.645)

Technology is a science and an art given its concern with the application of general principles to particular problems of production and utilisation. The technologist's education must develop a mastery of the theoretical concepts required for widely differing practical ends. The problems of production and utilisation can be solved only by the exercise of an art which is nurtured largely through cumulative experience in similar situations. While technological education in the universities is largely scientific, they are increasingly finding it desirable to relate the 'how' of engineering to the 'why'. Experience in industry is essential to the technologist and should grow in close relation to theoretical teaching, and therein lies the justification for sandwich courses.

ANDERSON, Sir D. 505

Education and training for the engineering industry

The Engineer Vol.204, 1957, 372-74

Sandwich courses are to have the same content of basic science as traditional university engineering courses. Hence the man graduating after a five year sandwich course will be much the same as the three-year university graduate after he has done a two-year postgraduate apprenticeship. There are now two routes to the same goal and a substantially larger number may well elect to take the sandwich course route. There is no reason why they should not do so; the choice depends not on intellectual ability but on personal taste and inclination. Many will welcome the earlier entry into industry now that the end result will be the same.

See also 602.

M'EWEN, E. 506

Training of engineers

The Engineer Vol.208, 1959, 223

Much present day 'practical training' is of doubtful value; a good engineer need no more be a skilled turner than the company secretary need be a skilled typist. The principal value of practical training is getting to understand the mind of the man on the shop floor, something about organisation and methods, and a general grasp of

engineering processes. For these reasons practical training in college workshops away from industry is valueless. Too many graduates have never been inside an engineering works; experience of the engineering environment should begin long before graduation, during vacations for example.

See also 204, 702.

ROBINSON, F. and WINDER, R. 507

Vacation training of undergraduate engineers

The Engineer Vol.208, 1959, 743-44

Traditional methods of training students and graduates in industry have lately come in for criticism, particularly those placing emphasis on the acquisition of craft skills. An experiment in vacation training has been carried out by the Mechanical Engineering Department of the University of Durham, designed to interest the students intellectually as well as practically through the investigation of certain chosen technical problems which the participating firm wished to solve. Both the university and the company's staff felt that the course achieved its objectives. The students gained practical experience to place into a different and more realistic context their own theoretical knowledge. The company welcomed students' recommendations, after looking at existing problems in a different way. Certain recommendations which were practicable would be adopted in the near future.

VENABLES, P.F.R. 508

Sandwich Courses for Training Technologists and Technicians (Max Parrish, 1959, pp.160)

An examination of the 'teething problems' of a new and important form of technical education. Focusses on the selection of students; content of courses; standards of examinations; industrial training; duration of courses; overseas students. Poses questions rather than suggests 'solutions', but at the present time this is probably the most important task facing those concerned with the development of sandwich courses.

JAHODA, M. 509

The Education of Technologists (Tavistock Publications, 1963, pp.226)

A study of the Diploma in Technology as operated at Brunel C.A.T. The process of education experienced by students, staff, and personnel in collaborating firms is examined, to assess the educational value of the industrial training period and the organisational and administrative problems of the sandwich course. Many examples from students' actual experiences illustrate the importance of appropriate and satisfying industrial training to the development of the individual. Analysis of empirical data provides the means for identifying the conditions and type of practical training conducive to a constructive learning experience.

BOSWORTH, G.S. 510

Education and training of engineers: what do engineers do?

The Engineer Vol.217, 1964, 927

University courses in engineering have developed, quite divorced from workshop practice. There is a feeling, however, that some initiation in craft skills is necessary for the young professional engineer, but this has become a ritual rather than a purposeful part of education. The division between the academic training and the practical experience is sharply marked. They are carried out in separate institutions by different people who have little in common with each other, and the true purpose of both parts is frequently overlooked.

See also 211, 412.

BOSWORTH, G.S. 511

Education and training of engineers: steps towards solving the problem

The Engineer Vol.217, 1964, 1025-26

What the engineer has to do runs across simple classifications such as mechanical, or electrical or civil. Each product requires knowledge and ability outside the arbitrary groupings adopted for teaching. The bridge between these classifications and the formal ones has to be built for each engineer coming into industry, and it has been tacitly assumed until now that this will be done in the industrial training in addition to all the other things which this training is supposed to achieve. This under-estimates the size of the problem, and its solution does not lie in a wealth of postgraduate courses in particular engineering science topics. What are needed are advanced courses in particular product technologies.

BALDWIN, C.T. 512

Industry, universities and engineers

Proceedings of the Institution of Electrical Engineers Vol.117 (3), 1970, 661-63

Although universities operating sandwich courses have found many satisfying features in the relationships thus established, much remains to be done. The integration of industrial and academic training requires continuing study and experimentation. Closer liaison on the number of university and industrial training places could be attempted, and this type of course should be recommended to the schools. It would be no bad thing if all engineering students followed a sandwich course. This would result both in a more satisfactory relating of academic and industrial studies and a more rapid development of a mature outlook in the student.

See also 321.

COHEN, L. 513

Linking university studies and industrial training

Vocational Aspect Vol.22(52), 1970, 57-61

Central to the philosophy of sandwich courses for engineering students is the belief that the period of industrial training enables students to integrate academic study with first-hand, practical problems within

industrial organisations. Full integration demands a policy of joint planning and continuous evaluation on the part of university and industry at each stage in the design and conduct of the industrial training period. It presupposes a level of mutual cooperation, which research into sandwich courses suggests is rarely achieved at the present time.

COWAN, J. and McCORNELL, S.G. 514

Project work for undergraduate engineers

Universities Quarterly Vol.24(4), 1970, 433-39

Project work carried out at Heriot-Watt University suggests that learning may be more effective when student-centred. By studying a particular problem in depth, through project work, the inexperienced student can learn, without external prompting, to recognise the vital role of the fundamental subjects studied prior to specialisation, and to think for himself in new situations demanding vision in problem solving. Moreover, the vocational orientation of engineering students can be utilised by involving them personally in a realistic engineering situation.

HINTON, Lord 515

Engineers and Engineering (Oxford U.P., 1970, pp.75)

A far higher proportion of professional engineers than in the past is being given a university education and that proportion will increase in the future. In one respect they are at a disadvantage in comparison to their predecessors, in that without apprenticeship training they never experience real work on the shop-floor. Thus, it is inadvisable for an intending engineer to go straight from school to university. It is better that students follow the 'thick sandwich' pattern and gain one year of workshop experience before university and a second after graduation. This is the best course for university training of engineers, preferable to the 'thin sandwich' courses, which have some danger of lack of continuity, both at the university and in industry. However, either the 'thick' or 'thin' sandwich course is better than post-graduate apprenticeship.

See also 324, 419, 614.

BROWN, A. 516

The education of professional mechanical engineers

Proceedings of the Institution of Mechanical Engineers Vol.185, 1970-71, 621-24

Formal education and industrial training should be considered as a whole and not as two distinct phases. Industrial training can be considered as the acquisition of firsthand experience in manufacturing techniques, design methods and industrial organisation. At certain stages in a student's career he will be most receptive to a particular part of his industrial training. Immediately after a student matriculates at 18 he is most suited to training in manufacturing techniques. He must be brought into contact and work with designers during his formal education. If extensive studies and experience of industrial organisation are required, it is preferable for them to be tackled after the period of formal education and real, rather than artificial, projects should be used.

See also 420.

DANCE, H.E. 517

The chartered engineer

Project No.17, Autumn 1971, 14-16

There were two historical weaknesses about industrial training but they are now being corrected: there was insufficient coordination between the college and industry, and it was left to the industrial firms to decide what should be done in the way of industrial training and for whom. The engineering institutions have established standards of training for professional engineers; industry has been closely involved and has ensured that the training and education provided is adequate to meet the needs of industry itself.

See also 616.

HORNSBY-SMITH, M.P. 518

Student experiences in industry

Vocational Aspect Vol.23(55), 1971, 81-89

The desirability of getting students into industry for a period of their undergraduate training is a conventional wisdom for which there does not yet appear to be any over-riding empirical support. There are a number of distinct types of student experiences in industry and in many cases these do not improve the undergraduate's image of industry. Further research is needed on the various types of industrial experience and their impact on student perceptions, given the long-standing belief that the interests of industry would be promoted by students gaining 'a true impression of industry'.

CHALLIS, H. 519

Why 'educate' engineers?

Engineering Vol.212, 1972, 28-9

The professional training of an engineer is not a valid educational objective - although it may use some of the techniques and contents of education - but is more accurately regarded as industrial training. Therefore, industry ought to shoulder the main responsibility for the induction and preparation of its own recruits at the outset. Educational institutions of higher learning would then be free to educate special talents in the vital and integrated field of technology. The output from such a discipline would enrich such technologically illiterate areas of social control as government, politics and industrial and public sector management.

PARNABY, J. 520

The university viewpoint

Tomorrow's Engineers: Proceedings of a Conference held at Bradford University ed. B. Wood (University of Bradford, 1972), 19-21

Integrated university sandwich courses for the education and training of professional engineers offer considerable advantages over traditional three-year undergraduate courses, and provide the best method for the training of engineers. However, the anticipated steadily increasing support from industry for sandwich courses has not materialised and,

in fact, most universities have found that support for their courses has reduced. It is vital that if industry believes in the value of sandwich courses it should be seen to endorse them by giving steady consistent support. The universities' aim is to achieve continuous practical working relationships with a wide range of industries.

WALKER, V. 521

A new look at course content

Tomorrow's Engineers: Proceedings of a Conference held at Bradford University ed. B. Wood (University of Bradford, 1972), 2-7

Headmasters sometimes comment on a potential student that he is of only average academic ability, and therefore he is perhaps more suited to the practical emphasis of a sandwich course. This is a misconception; one supposes that ultimately all potential engineers are intending to become practical engineers. The sandwich course is simply intended as an arrangement, which integrates practical training and academic studies more effectively; it does not imply a diminution of academic standards.

See also 330.

CROSSLAND, B. 522

University undergraduate education in engineering

Proceedings of a National Conference on Engineering Education ed. A.S. Goldberg (Education and Awareness, 1973), 125-30

The education and training of engineers have come to be thought of as distinct functions, whereas they are part-and-parcel of the same function just as much as in medicine. Although they may be carried out in separate establishments there must be close, not just nominal, collaboration between those in education and those responsible for training in industry. The continuing dichotomy between education and industry is doing irreparable harm. Industry must provide well considered training, agreed with the educational institution concerned, and provide some of the ideas for design and experimental projects in engineering courses. Industry may feel this would be a heavy burden but if we are to have well trained and educated engineers it is a price that must be paid.

DANIEL, D.W. 523

Sandwich courses in engineering

Proceedings of a National Conference on Engineering Education ed. A.S. Goldberg (Education and Awareness, 1973), 165-73

The sandwich course is the best method to educate and train an engineer. However, higher education and employers should try to provide students with more 'relevant experience' during their placement periods. It would be advantageous for engineering students to spend some of their training periods in departments such as accounts, costing and sales, rather than be expected to spend all their time in the engineering or production environment. During their first appointments engineering graduates perform managerial and supervisory tasks for which they are not fully prepared because of the present structure of education and training.

PREECE, D.A. and FLOOD PAGE C. 524

Sandwich course undergraduates and industrial experience

Vocational Aspect Vol.26(65), 1974, 95-104

A survey of sandwich course students at the University of Bradford suggests that although they tend to like their industrial training period, it is perceived as a distinct experience and not part of an integrated whole, connected to the academic experience. Indeed, following the industrial period the students exhibit less enthusiasm for their course and become unclear as to the goals of the course: important problems for anyone concerned with sandwich type courses. It may be that the reduction in academic enthusiasm at the mid-point in a course is a general phenomenon rather than one specific to sandwich courses.

BRANCHER, D.M. 525

Projects and the development of general education

European Journal of Engineering Education Vol.1(1), 1975, 36-40

Engineering education faces two main problems - the need to accommodate some of the changing values in society, and the need to develop autonomous learning habits in readiness for permanent education. Project work represents the best learning method which will meet these needs and at the same time instil a realization in students that engineering is a social activity. This is because projects dealing with issues and problems in the context of engineering allow personal involvement and original activity, which have an essential mediating function in any changes of attitude.

CORNWALL, M.G. 526

Sandwich course training and project work: do they have the same aim?

European Journal of Engineering Education Vol.1(1), 1975, 42-47

The education and training of engineers should be directly concerned with the development of generalised professional abilities and attitudes. Conventional didactic approaches to higher education are grossly inappropriate for such development. Sandwich course industrial training and project work have the potential for the attainment of these 'new' goals. At present the lack of a clear specification of what can be achieved by these approaches and a confusion of perceived aims, means that this potential is generally wasted. Courses need to be re-orientated to provide a genuine integration of professional training with academic studies.

LEECH, D.J. 527

Undergraduate training in design project management

International Journal of Mechanical Engineering Education Vol.3(1), 1975, 77-83

The degree in Industrial Engineering was established by University College of Swansea with the aim of producing generalist engineers conversant with the multi-disciplinary nature of most real engineering projects. In the third year each student works on a personal project and a group project. Such work is of value by teaching problem solving, generating interest in available techniques, and by making students think for themselves. If projects are to instruct in project management they need to be large, industrially based group projects. The

success of this method depends on careful preparation by the academic supervisor and commitment from an outside company in providing a real design problem.

TOPPING, J. 528

Sandwich courses

Physics Education Vol.10, 1975, 141-43

The greatest limiting influence on the expansion of sandwich courses has been the availability of suitable industrial training places; colleges have had to devote more and more time and effort to this task, and in consequence some turned to full-time courses on the traditional pattern or restricted the amount of practical training included in their courses. Yet for many students this mode of education is the best way of developing their learning powers. Also the satisfaction in learning practical skills, the sense of independence and growing maturity of students arising from their industrial experience and mixing with people of different backgrounds, skills and outlooks, are other elements in sandwich course education which are not to be underestimated.

See also 334.

McLAIN, L. 529

A scheme is needed to fill better the role of sandwich courses

The Engineer Vol.243, 14 October 1976, 56-7

Shortages of engineers and their low status in the eyes of the young are causing concern in Whitehall as industry continues to take a back seat to more desirable careers. But suggestions from the DoI for greater use of sandwich courses as a way of encouraging students into technological education ignore recent evidence that such courses do not fulfil their traditional objectives. Indeed, previously enthusiastic students of engineering have been dissuaded from taking their interest any further by their experience of industrial training. The situation is such that the parties involved should examine the reasons why industrial training instils damaging disinterest among many keen engineering students, and this implies a re-assessment of Britain's sandwich course approach to industrial education.

SMITHERS, A.G. 530

Sandwich Courses - An Integrated Education? (National Foundation for Educational Research, 1976, pp.180)

In Britain the value of industrial training in the education of advanced technologists has been taken as self-evident. However, a study of the operation of sandwich courses by the School of Educational Research at the University of Bradford shows that they are not achieving their traditional objectives. Instead of encouraging students who have opted for an industrial career, industrial training tends to foster disillusionment in them, and this negative feeling develops with each shopfloor experience. The 'teaching company' may be what is needed to replace outmoded sandwich courses. The 'teaching company' would enable a technology student to study and work in the environment of a company 'with the company's interests in mind', whereas in current sandwich courses students feel isolated from a firm's role.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE 531

Education, Engineers and Manufacturing Industry

(University of Aston, 1977, pp.59)

Universities and polytechnics, industry, the professional Institutions and appropriate training boards have parts to play in the education and training of engineers. The present system is ill-defined and performance is mixed. There is an urgent need to improve the integration and coordination of the education and training phases. Any new proposals must, however, cater for diversity; a single solution is unlikely to prove satisfactory. The responsibility for ensuring that a graduate has received adequate education and training should be with the educational institutions, and the professional Institutions should concentrate on monitoring the integrated education and training schemes rather than monitoring the individual.

See also 337, 722.

BILLAU, D.J., CLEGG, A.J., and KNIGHT, J.A.G. 532

Practical training for potential professional engineers at Loughborough University of Technology

European Journal of Engineering Education Vol.3(1), 1978, 55-65

The primary function of the Centre for Industrial Studies at Loughborough University is the provision of on-campus professional practical training for undergraduate engineers. The centre can provide the student engineer with a comprehensive appreciation of the many production processes avilable, whereas few companies have the facilities to do so. Training is given in craft skills and students undertake both individual and group project work. Student performance is monitored through the use of log books, staff assessment and viva voce examinations.

BROWN, G. and MATLEY, W. 533

Engineering training through practice as well as theory

European Journal of Engineering Education Vol.3(1), 1978, 43-54

The Electronic and Electrical Engineering Department of the University of Surrey places great emphasis on the instillation of practical skills at each stage of the teaching process. Employing firms of graduates from the department report that they have the knowledge and motivation to play a significant part in the activities of companies very quickly. One of the major factors must be the development of applicable skills along with fundamental expertise. In general educators must appreciate that it is essential for the young engineer to acquire practical skills, and students must be given opportunities to train through practice as well as theory.

See also 343.

BREWER, R.I. 534

Science and Engineering Education Policy: The Work of Willis Jackson, Baron Jackson of Burnley (1904-1970)

M.Sc. Thesis, U.M.I.S.T., 1978

Two themes run through Jackson's involvement in policy-making for science and engineering education - the academic and industrial influences. These reflected the duality of his own career and are demonstrated in his promotion of undergraduate courses for 'industrial

technical specialists', combining knowledge of science with experience of industrial skills. To that end Jackson advocated collaboration between educational institutions and industrial organisations, and the development of sandwich courses in engineering education.

See also 225.

EDWARDS, Sir S. 535

The urgency of education

New Scientist Vol.78, 1978, 656-7

Britain has a complete educational system in the sense that one can point to a sector of the system which is supposed to provide the educational needs of any activity of the nation. The difficulty is that a great deal of it does not work well and some parts not at all. Thus, although the school and university parts of training a professional engineer work well, data from the Engineering Industry Training Board show that the professional training part of the engineer's career, is far from universal. It is indeed done by a minority in spite of the repeated extolling of its virtues by institutions and experienced individuals. In contrast, training in the teaching hospital is an integral part of the process of qualifying as a medical practitioner.

FERGUSON, J.M. 536

The twin pillars of engineering

Proceedings of the Institution of Electrical Engineers Vol.125(1), 1978, 1-7

Sixty years ago the pattern of technical education consisted of part-time instruction combined with practical experience, with a limited number of full time students at universities or colleges. The making of an engineer was firmly established on the twin pillars of engineering - the practice and the theory. With the expansion of higher education the route to chartered status for those with the ability and perseverance to study while working in the manufacturing environment has largely been closed. At the same time the modern pattern of education may have inadvertently encouraged a bias against manufacturing as a suitable area in which to pursue a career in engineering.

FRANCIS, J.R.D. 537

The British system of engineering education

European Journal of Engineering Education Vol.3(1), 1978, 3-15

There is much interest in the U.K. in project teaching and this method is popular with both students and teachers. However, experience is beginning to reveal some disadvantages in project work. Students are notoriously slow workers so that a great deal of time is used for relatively little result. The less able student may require so much help that their final documents may be principally the ideas of the teacher. Teachers find it difficult to anticipate whether a project will be too difficult and time-consuming or if it will be trivial. Doubts arise on the value of projects in comparison to the volume and breadth of formal work which could be done in the same time. Also work generated in an academic environment, even when the original idea comes from industry, may well be artificial and does not introduce the real constraints to the work that would apply if it was being done in the industry.

LOWREY, J. 538

Industry now has a role to help improve graduate quality

The Engineer Vol.246, 16 March 1978, 42

One persistent criticism from industry aimed at universities is that engineering courses are not relevant to the 'real world'. Industry has now been offered the opportunity not only to have its say but become actively involved in the design of new courses to be set up at Brunel, Imperial College, Strathclyde, Manchester and Birmingham. The greatest contribution from industry is needed in the area of industrial training periods, which to date have done little to help bridge the gap between study and training. The addition of sponsorships should provide firms with the added incentive to take an active interest in the students for it is here they stand to benefit most. If these new special engineering courses are a success industry will no longer be able to blame universities for graduate quality.

FLOOD, J.E. 539

Industry and education

Proceedings of the Institution of Electrical Engineers Vol.126(3), 1979, 281-82

It is inevitable that there will be a shortage of engineers of the highest technological competence and of those with the personal qualities needed to reach the highest levels of management. When universities are criticised for not producing enough broadly educated and trained engineers with professional competence, industry confuses education with training and fails to understand that education is not a 'one-shot' process which ends on graduation. If graduates are not immediately useful to industry, the remedy lies in the hands of industry itself. But universities committed to sandwich courses are unable to obtain sufficient training places for students from reluctant industry. If training was seen to be essential, this would not be so.

LEWIN, D. 540

On the place of design in engineering

Design Studies Vol.1(2), 1979, 113-17

To achieve the objectives of a systems approach to engineering education students must become personally involved in the problem-solving activity. Thus, the teaching mode should be primarily project work. Students need not obtain a detailed technical solution to the system problem, but they should appreciate the difficulties of problem specification and experience the evaluation of trial solutions - the essential theory testing process. Projects should involve the student in human as well as economic and technical considerations.

See also 232, 436.

ALBU, A. 541

British attitudes to engineering education: a historical perspective. In *Technical Innovation and British Economic Performance*, ed. K. Pavitt (Macmillan, 1980), 67-87

The engineering institutions should relinquish their claim to responsibility for qualifications and their attempts to monitor the practical training of the engineer. If degrees were awarded only after the required practical training had been satisfactorily completed it would

then follow that the responsibility for monitoring a student's training would be that of his teachers, and industry should accept their right to do so. Industry should accept the responsibility for the practical side of an engineer's training and should cooperate with the institutions and educational establishments in determining the nature and content of academic courses and practical training.

See also 733.

CLEMENTS, I. 542

The Vocational Education and Training of Technicians and Engineers (2 Vols.)

Ph.D. Thesis, Keele, 1980

An examination of the education and training of technicians based on an empirical enquiry conducted through a postal questionnaire survey of technicians employed in industry. Includes a recommendation that the part-time route to Chartered Engineer status should become the primary route into the engineering profession. Thus, graduate engineers would undertake a minimum period of full-time industrial experience to bring them up to the equivalent competence of more experienced colleagues who qualified via the part-time route. Evidence from the survey suggests that engineers are much more in favour of 'work experience' than 'industrial training' combined with further education, i.e. contrary to current practice and post-war trends.

FORD, Sir H. 543

Engineering education and the new professional requirements: the educationalist's viewpoint

European Journal of Engineering Education Vol.5(1), 1980, 43-51

Engineering is a matter of doing and of solving problems and taking decisions and these things can only be thoroughly learnt in the environment of the industry in which the engineer finds himself. There is now a much better understanding of the fact that universities and industries must work much more closely together so that the application of fundamentals and techniques are seen and appreciated in the environment of all the boundary conditions and constraints. There are three main requirements: non-technical studies in university courses; shop-floor experience; and professional development of the young engineer through supervised involvement in actual industrial problems.

See also 349, 438.

GLASSBORROW, A.M.C. 544

An Evaluation of the Industrial Training Period of a Sandwich Course for Undergraduate Engineers

Ph.D. Thesis, Brunel, 1980

Concerned with the identification of the objectives of the training period, the process of training, and an assessment of the achievement of the objectives. Seven general objectives are identified and from an analysis of the three main parties in the sandwich course system (students, academic and industrial supervisors) the relative priorities of the objectives are established. This is followed by an assessment of their achievement. Against all but one of the main criteria a favourable response was received from the majority of the sample population involved in the study.

TOMKINS, R. 545

Educating the engineer for innovative and entrepreneurial activity

European Journal of Engineering Education Vol.5(2), 1980, 97-159

A major objective of engineering education should be to ensure that an awareness of the importance of innovation pervades all its activities. There is much questioning of the extent to which innovative and entrepreneurial attitudes can be taught or whether they can be taught at all. However, positive attitudes towards innovative activities can be influenced by active learning methods, through students learning from others or from experience. In promoting such attitudes project methods and integrated periods of practical industrial experience must play a major role in engineering courses.

See also 350, 440.

FORD, Sir H. 546

'Through thick and thin' - the education and training of mechanical engineers

International Journal of Mechanical Engineering Education Vol.9(3), 1981, 189-98

For too long universities played down the vocational aspects of engineering education. The prevailing attitude favoured academically respectable courses in engineering science with students being left to learn about industry after graduation. The Total Technology course at Imperial College was established to interweave the industrial and academic aspects of engineering in a five year package which commences with a preliminary year in industry, before teaching in the fundamental sciences takes place. Such a package should provide an education and a balanced introduction to engineering competence.

See also 352, 625.

HUTTON, S.P. and LAWRENCE, P.A. 547

German Engineers: The Anatomy of a Profession (Clarendon Press, 1981, pp.151)

The feeling in Britain that the university-educated engineer will be too theoretical, too little able to apply his knowledge, and quite probably too conceited as well, runs very deep; it is an attitude which must be combated, and a system of undergraduate engineering education which guarantees some direct experience of industry is a contribution to this end. Thus, a compulsory period in industry, either before or during the undergraduate course (or both) is essential. Practical training and industrial experience should be prerequisites or components of the undergraduate course, rather than appendages to it, in the form of post-graduate training in industry.

See also 734.

MAILLARDET, F.J. 548

'In search of reality': the role of design studies in engineering education

European Journal of Engineering Education Vol.5(4), 1981, 309-18

In design education it is impossible to teach engineering students the vital application, methodological and team skills from a theoretical standpoint. Firstly, students can be misled into assuming the real world comprises perfectly defined conceptual models; secondly, because

so few students have experience of practical engineering, lectures on design methodology are unlikely to be profitable as they have no experience to which they can relate the teaching. The answer is clearly to accelerate the experience of students by exposing them to a team design activity as early as possible in their education. Mechanical Engineering students at Brighton Polytechnic engage in design activity in both the second and third years of their course, through which they are ultimately able to apply relatively advanced specialist material in a project situation.

See also 442.

CHISHOLM, A.W.J. 549

Government financing of university engineering education in Britain (pt.2)

International Journal of Mechanical Engineering Education Vol.10(3), 1982, 185-94

Britain has a strong tradition of part-time engineering education in technical colleges which has influenced the approach to university engineering education. It consolidated the idea that universities provide education in engineering science, while industry provides training in the application of engineering science in practice. The scientific orientation of university engineering courses has also been consolidated by the engineering institutions' insistence on fundamental science in the university, and by their emphasis on industry's training role in bridging the gap between knowledge and application.

See also 135, 736.

CHISHOLM, A.W.J. 550

Some problems of Government financing of university engineering education in Britain

European Journal of Engineering Education Vol.7(3), 1982, 271-88

The engineering institutions' emphasis on retaining a requirement for a period of industrial professional training has helped to consolidate the scientific orientation of university engineering education, and has discouraged the structured teaching of professional engineering practice necessary to prepare students adequately for an engineering career. The failure of the existing 'dual system' of engineering education and industrial training to provide the necessary range and quality of engineering skills has led the Engineering Professors' Conference to propose the lengthening of degree courses by one academic year as soon as practicable for the majority of engineering students.

See also 133.

MORRIS, D. 551

Engineering design and manufacture

Engineering Design Education Spring 1982, 25-29

The movement from a three to four year degree course should be used to integrate directly into the degree an early appreciation of the industrial application of classroom material via direct involvement with local industry and meaningful project assignments. The University of Hull's department of Engineering Design and Manufacture has established contacts with companies to collect a range of design-type problems which are matched to the abilities and experiences of its students and which can be realistically attempted in the time available. Small group and individual work on these design projects can demonstrate the methodology of coping with open-ended problem-solving and develop decision-making confidence.

See also 444.

6. EDUCATING ENGINEERS FOR MANAGEMENT

The interest in management education for engineers derives in part from the concept of professional engineering as a multi-disciplinary activity; it is one way of moving towards a broader education for engineers. However, the case for educating engineers for management rests on other important considerations too. It is apparent that the balance between the technical and non-technical responsibilities of the practising engineer changes as his career develops. The initial emphasis on deploying technical expertise is, over time, replaced by an increasingly managerial role within the firm or organisation. The consensus view has been that engineers are generally ill-prepared for such a role by their undergraduate education, and this deficiency can be remedied by the inclusion of management studies in engineering courses. A further dimension to this issue is provided by the scarcity of engineers in the upper reaches of industrial management. This situation is often explained by reference to the historically narrow engineering curriculum which places the engineer at a disadvantage relative to those professional groups with a more broadly based education, and to the lack of training in management skills specifically. Thus, we find several reasons advanced to justify the inclusion of management studies in the engineering curriculum. What is generally absent from the literature on this issue is a clear idea about what engineers need to know and be able to do in the management sphere when they leave university or polytechnic.

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KASTNER, L.J. 601

Education, Tasks and Outlook of the Engineer

University College Swansea, Inaugural Lecture, 1950

Education in science and technology has paid too little attention to problems of training for management in industry and elsewhere, and as a result has produced many people who are expert in dealing with technical problems but who shrink from the great human problems which industry presents. Thus, engineering education should not concentrate exclusively on the materialistic and scientific aspects of the profession, but provide the wider training required by the modern engineer.

See also 101, 301, 501.

ANDERSON, Sir D. 602

Education and training for the engineering industry

The Engineer Vol.204, 1957, 372-74

To be efficient the engineering industry must have good management, because without this the maximum return cannot be reaped from technological advance. Management Studies should therefore have a place in engineering education. Training for management must comprise two parts. First the acquisition of knowledge in subjects like industrial history, economics, psychology, industrial relations and work study; and second, opportunities for practice in the art. This means a cooperative effort between teaching institutions and industry, and of all branches of study. But the reactions of human nature on the shop floor have no counterpart in any classroom experience and if the standard of management is to be raised industry must organise proper schemes of practical training.

See also 502.

SMITH, Sir E. 603

Management and the engineer

Proceedings of the Institution of Mechanical Engineers Vol.172, 1958, 1097-1104

Management involves the organisation and control of human activity directed to specific ends. The training and subsequent experience of the professional engineer should be well suited to the development of good managerial qualities. Every engineering activity has a clear and immediate purpose, the achievement of which demands planning, decision, and control. The engineer is reared on the idea of change and progress. He has to carry responsibility for his work and results. Engineering, too, always depends on cooperative action. But British engineers, relative to the contribution they should be able to make, are not numerically outstanding in management, either in industry or government.

See also 701.

CHRISTOPHERSON, D.G. 604

The theoretical training of the engineer

Chartered Mechanical Engineer Vol.8(6), 1961, 364-67

There is a basic contradiction in engineering education. The scientific and technical knowledge required by the professional engineer has at least doubled in the last twenty-five years but the time available for his education has remained unchanged. A fundamental re-think is needed, in the context of industry's use of professional engineers. The engineer is engaged in two broad classes of work: research, development and design (the scientific occupations) and production, planning and management (the economic activities). Universities should provide two kinds of engineering education, with degree courses in 'Engineering Science' and 'Industrial Engineering', in order to meet the need for engineers with both technical and managerial skills.

PARKES, E.W. 605

The Education of an Engineer

University of Leicester, Inaugural Lecture, 1961

A distinctive feature of engineering activity is the amount of time devoted to decision-taking. As yet the universities cannot teach a science of decision-taking. What they can do is show the background to decision-taking - the sort of information and considerations which enter into it - and also its results. Thus, the future engineer-manager can acquire knowledge of the factors which influence industrial decisions, but he cannot be taught by the university how to make those decisions.

See also 312, 408.

EDGEWORTH JOHNSTONE, R. 606

Some thoughts on engineering education

Nature Vol.193, 1962, 618-22

Many young chemical engineers are meeting administrative and economic problems quite early in their careers, and are using much more social science of one kind or another than they were taught at college. We can no longer afford to teach only physical science at university and

expect the young engineer to pick up social science as he goes along by applying his scientific training to human problems. If there is a science of human behaviour, and if the engineer as manager is expected to apply it, then he must be taught to think scientifically about social problems just as about physical problems: and that surely is a job for the university.

See also 207,705.

BRANDY, K. 607

Professional Employees: A Study of Scientists and Engineers (Faber and Faber, 1965, pp.197)

Many engineers are employed in positions in which they either share directly in the exercise of authority or in which their work gives them the feeling of being close to management. Thus, they accept the employers' ideology of stratification, that they are part of a graded hierarchy. This is manifested in the professional associations. Of those who do not share in the exercise of authority, some will experience work conditions which emphasise their subordination. These individuals are likely to have attitudes which are more of a class type, and elements of this are found within the professional associations. The more these work conditions are present, the stronger will be the class attitudes, until eventually there comes a major change. For the individual this means a recognition of a conflict of interest with the employer, an acceptance of collective bargaining and membership of a trade union. However, the class viewpoint is largely restricted to the employment situation and status attitudes remain, having a strong effect on the activities of the union.

BURROWS, C.R. 608

Educating engineers

The Engineer Vol.223, 1967, 372

The lack of impact of engineers in management and government has been commented on by many writers. The reasons for this are varied, but in discussing the education of engineers it is reasonable to comment that educationalists could help right the balance by stressing the social and economic responsibilities of the engineer in addition to his technical function. It is to be hoped that the CEI, having made a start towards more vigorous theoretical training, will now provide the needed impetus and direction to evolve an enlightened attitude towards the education and training of engineers in both the universities and colleges and in industry.

See also 711.

EARLE, A.F. 609

Management and the engineer

Proceedings of the Institution of Mechanical Engineers Vol.183(1), 1968-69, 739-44.

Engineers were the first managers. Their pre-eminence has been overtaken by accountants and men of broader training, and the acceleration of business studies will increase this displacement. British management would benefit from a higher number of men who

combined an engineering training and viewpoint with broad management understanding. Through postgraduate business studies courses and the introduction of four-year degree courses in engineering (affording better treatment of social science subjects) it is possible that graduate engineers will be better prepared for management opportunities in the future.

See also 712.

TURNER, B.T. 610

Management Training for Engineers (Business Books, 1969, pp.401)

The switch-over from engineering to management will involve the engineer in an acceptance of the fact that management can never be an exact science. An engineer deals with ideas and hardware; his education lays emphasis on the use of materials and natural phenomena and not enough upon manpower and money. Engineering, by its very nature, leads to 'tunnel vision'; the manager has to take a 'wide-angle' view. It is important that engineers overcome such handicaps because accountants have dominated the top management structure in British industry for too long. While finance is important, survival is likely to depend on marketing and design ability as well as financial viability.

CARY, Sir H. 611

Management in the engineering disciplines

Proceedings of the Institution of Mechanical Engineers Vol.184(1), 1969-70, 1212-19

The growing number of specialisms in engineering presents increasing problems to management. In cases of difficulty the manager either has to consult specialist experts or take decisions in fields in which he has no particular competence. The availability and future development of computers may offer a better solution. By carrying out many processes that now form part of the professional syllabus, the computer could make it possible to cover in a single course groups of subjects now requiring separate courses; professional work would be more broadly based, and increasingly concentrated on value judgements. A more generalised first degree course and later specialisation not on single subjects but on related groups could evolve.

DIAMOND, J. 612

University engineering education 1960-1980

Advancement of Science Vol.27 (132), 1970, 164-70

Many in industry hold the view that university engineering graduates are too much wedded to science. They do not understand the practical needs of industry and are not motivated towards the solution of its problems. However, within the diverse pattern of British engineering education there has emerged over recent years a number of common developments in course content which take more consciously into account than previously the broad nature of engineering activity - broader, that is, than the applied science aspects. Thus, economics, management and administration have begun to play an increasing role in the syllabus.

See also 322.

FOECKE, H.A. 613

Engineering in the humanistic tradition

Impact of Science on Society Vol.20(2), 1970, 125-35

It is in the nature of the engineer's work for him to recommend what should be done as well as determine what can be done. The education of the engineer, therefore, should be broadened to include more studies in human and social sciences. The practising engineer has to exercise social responsibility in decision-making and formulating recommendations, and this not only involves technical considerations but also other factors, such as economics, culture, aesthetics, and safety.

HINTON, Lord 614

Engineers and Engineering (Oxford U.P., 1970, pp.75)

Management is involved at all levels in the engineering profession. All engineers need to know something about management but the overall management of business enterprises involves not only engineering knowledge but also skills that are not technological. In top management the day of the individual has gone and management of large enterprises is now a team effort. The team is made up of people whose training was in many different disciplines, including engineering, but engineering training does not necessarily qualify people for leadership of the team. Business schools and schools of management can prepare people from different backgrounds for management roles but sophisticated techniques of management must be taught on the basis of concern for the individual within the organisation.

See also 324, 419, 515.

KERENSKY, O.A. 615

Fuller education and training of engineers

The Engineer in the Community (Institution of Civil Engineers, 1970), 8-14

At some point in their careers most engineers will have managerial responsibility, even if only a proportion will reach the top management positions. It would be harmful for any nation to entice too many of the gifted engineers into higher management at the expense of engineering pursuits. Education for higher management should not, therefore, be part of the ordinary degree courses, but should be available to the promising candidates as part of their continuous education. The best foundation for this is a broad university education, for as the engineer gathers experience, he will become educated in management by the practice of management.

See also 325.

DANCE, H.E. 616

The chartered engineer

Project No.17, Autumn 1971, 14-16

Engineering is technology plus management. Engineering operations entail a wide range of management skills from the most modest level of supervision of a detail, to total responsibility for a major work. There is always some form of higher management, whether engineering is done within the organisation of a commercial firm or within the

framework of a public service: it is responsible for policy, for the general direction of the departments of market research and sales, research and development, design, manufacture and, most importantly, manpower.

See also 517.

de la MARE, R.F. 617

The graduate chemical engineer's dilemma: 'technology or management?'

The Chemical Engineer April 1974, 210-11

Many graduating chemical engineers enter industry with aspirations of becoming managers; few however make the grade. This results in part from misconceptions of what constitutes management, and in part from the inability of some engineers to marshal the management talent commensurate with their management ambitions. Engineers in management need to be as much aware of corporate needs as technical detail, and to develop better inter-personal skills. At present too few graduates attempt to evaluate their own management capabilities, and they receive insufficient help from their universities to do so. The transition from engineering *per se* to management requires more effective monitoring by employers too if it is to be successful.

WEARNE, S.H. 618

Management studies for professional engineers

International Journal of Mechanical Engineering Education Vol.2(1), 1974, 1-10

Engineering depends upon more than the application of technical science. Engineering graduates should therefore have some comprehension of the social and economic variables which will affect much of their work in industry. A distinction can be made between the preparation for initial employment and the later preparation for middle and higher management. At the undergraduate stage engineers should be given an appreciation of the wider problems affecting technical decisions; those with the talent and interest for management *per se* will require further preparation at a later stage. Educators need to be clear about the needs of graduate engineers for non-technical knowledge and skills, and how best these objectives might be met; the inclusion of management sciences or 'broader studies' in undergraduate courses should be based on the definition of practical objectives.

GLOVER, I.A. 619

Engineers - the forgotten profession?

The Chemical Engineer January 1976, 42-44

Although British engineers may fill management posts, they do not reach top positions nearly as often as do their continental counterparts. British engineers are not trained to become 'top generalists'. They have an education which is a restricted preparation for a career and gives less social cachet than almost every other kind of higher education. The low position of the engineer in British management is linked to the relatively low standing of careers in industrial management. Engineering is a career chosen by those who expect to achieve only a restricted amount of upward mobility.

See also 224, 720.

FISHWICK, W. 620

The engineering professor's dilemma

Impact of Science on Society Vol.27(4), 1977, 369-77

In industry the managerial element of an engineer's work usually grows with his experience so that about 20 per cent call themselves senior managers. The functions of the engineering manager are as important as any purely engineering role. Before graduation, the student should be introduced to managerial methods as practised in his country. Formal courses are useful, but the student should be expected to read widely. He should try to judge what he reads in the light of what he knows concerning his own society's industrial environment. There are no 'correct' managerial techniques; there are only appropriate ones, practically tested, in real-life situations.

See also 338, 430, 723.

HEYWOOD, J. and MONK, J.D. 621

The education and career patterns of professional mechanical engineers in design and management

Vocational Aspect Vol.29(72),1977, 5-16

A sample survey of mechanical engineers suggests that engineers themselves see the development of managerial skills as the key to career advancement. It is the management function that enables the professional engineer to satisfy an ambition for status, responsibility and financial reward. However, they believe that the engineer in general has insufficient training in economics, finance and management studies which would enhance his opportunity of becoming a manager.

See also 431.

MUIR-WOOD, A.M. 622

Presidential address 1977

Proceedings of the Institution of Civil Engineers (Part 1) Vol.64, 1978, 1-23

The management of industry must be undertaken by those capable of undertaking a synthesis across several disciplines. The engineer of the future must be prepared to take a far more central role in this activity. Management and engineering are both creative arts acquired by thoughtful conceptualising of experience based upon techniques which may be taught; both require the ability to converse with specialists and to synthesize their contributions. However, radical changes are needed to permit the engineer to contribute adequately to industrial prosperity in Britain. Perhaps the most evident need is the realisation that immediate extraction of profit is secondary to the purpose of planning, designing, making and selling products.

See also 228, 728.

CROSSLEY, L. 623

A Comparison of Industrial Needs and Educational Aims in the Training and Education of Engineers

M.Phil. Thesis, Nottingham, 1980

An assessment of attitudes to engineering education and training based on a questionnaire survey of 132 engineers. Existing 'core' subjects such as engineering practice, theory and drawing were seen as essential

by most respondents, unlike social studies and materials. Other subjects suggested as necessary elements in engineering courses were marketing, human motivation, company law, work study, safety and communications. The question arises as to how these subjects can be accommodated without increasing the time spent in further and higher education, and when replies suggest that at present collaboration between industry and education is poor.

GLOVER, I.A. 624

Social science, engineering and society

Higher Education Review Vol.12(3), 1980, 27-41

It has been argued that Britain should aim to produce the 'technical generalist', hopefully so that more broadly educated engineers should reach the top in manufacturing. Yet the whole notion of generalism is fraught with danger for the engineer. Instead of being taught engineering skills, much more broadly defined than in the past, undergraduate courses are topped up with 'management education', concerned with relationships, decision making, etc. So the traditional tendency to over-emphasize the value of natural science is supplemented by emphasis on behavioural science, again at the expense of useful skills and broad education.

See also 129, 233.

FORD, Sir H. 625

'Through thick and thin' - the education and training of mechanical engineers

International Journal of Mechanical Engineering Education Vol.9(3), 1981,189-98

Professional engineering activity involves management and industrial relations but management courses for undergraduate engineers are to be avoided. Students should be exposed to the ingredients of good management in practice and not to the teaching of management science, which fails to induce the vital notion that management is concerned with people in their working environment, leadership and the acceptance of the leader in the workplace.

See also 352, 566.

WEARNE, S.H. 626

Engineers' managerial tasks

Journal of European Industrial Training Vol.5(6), 1981, 22-24

A survey of Chartered Engineers indicates that all engineers' careers include some managerial tasks, although many engineers remain in predominantly technical jobs. Most respondents felt inadequately prepared for their present and prospective jobs. Thus some subjects commonly taught in business courses are less relevant than others not commonly taught, such as project and contract management. Priority should be given to preparing engineers for inter-disciplinary project roles in industry, while recognising that the technical and managerial mix in engineering activity can vary according to the discipline and age of the individual.

ISAAC, P.C.G. 627

The future of university education in civil engineering

Future Needs in Civil Engineering Education (Institution of Civil Engineers, 1982), 49-55

The seeds of management knowledge should be planted during the undergraduate course. This helps the young engineer to cross the bridge between 'theory' and 'practice', and, more importantly, provides an intellectual approach to the senior engineer's most important practical task: to allow for, and deal with, the non-technical aspects of the problem he is trying to solve. The challenge involved in successful management is quite as satisfying as that involved in a complex analysis or design, and is perhaps more vital to the fruitful outcome of a project.

See also 356, 443.

ROOKE, Sir D. 628

Business skills for student engineers

Education and Training Vol.24(4), 1982, 128

The teaching of technological and basic business skills as an integrated experience in undergraduate engineering studies is an important requirement. In the real world there are few technical problems for which viable solutions are not influenced by other requirements of the business; thus 'elegant solutions' often have to be subordinated to the art of the possible. Students need to acquire business and communication skills in order to appreciate and cope with the economic, social and political implications of the engineering decisions they will be called upon to make.

TOLLEY, G. 629

Engineers and management

Proceedings of the Institution of Mechanical Engineers Vol.196, 1982, 333-35

The engineer takes his place as a manager more often than not with inadequate preparation for that role, but as the workforce in manufacturing industry declines the proportion of engineers in a management function must increase. It is a fallacy to believe that you make an engineer into a manager by grafting on a bit of knowledge about finance, organisation and marketing to technical skills. A broad consideration of the place of engineers in management requires that attention be given to developing certain skills: entrepreneurship, the management of change, and the ability to transmit the values of a technological society. A pattern of management development for engineers should be established which equips them for managerial roles not only in manufacturing but in other areas as well.

7. THE STATUS OF ENGINEERS AND ENGINEERING

Few writers on the engineering profession fail to mention its low status in Britain relative to that of other professional groups, and to that of the engineering profession itself in other countries. While pay is an obvious concern to engineers, they also feel that the public (and most politicians) neither understand what engineering is about nor appreciate its contribution to society. The engineer is undervalued, in more senses than one, by a society which sees science as the instigator of technological advance. This situation is not helped, say engineers, by the under-representation of the profession in key areas of a national life, e.g. parliament, the civil service, senior management in industry and the public services. Although this is not strictly an educational issue, it does, nevertheless, overlap with many of the issues discussed elsewhere in this volume. For example, can the low status of engineers, and their failure to project a clear image of themselves, be a reflection of deficiencies in their education which deny them the social and communication skills to match their technical expertise? Have engineers failed to penetrate some of the centres of power because their education has been too narrow in the past? Status is also significant educationally because there are links between the social and academic standing of engineering which have affected the ability of the profession to recruit its fair share of the most able students.

* * *

SMITH, Sir E. 701

Management and the engineer

Proceedings of the Institution of Mechanical Engineers Vol.172, 1958, 1097-1104

Relative to their potential contribution British engineers are not adequately represented amongst senior managers in industry and the public services. The main factor preventing engineers from taking a greater part in general management is the present acute shortage of engineers and other technologists, which tends to confine them to their own specialist work. However, there is also a conservative tradition which has often restricted the freedom of the technical man to gravitate to administration and management. In part this has been reinforced by the increasing technical specialisation of engineering and its inability to provide a broad education.

See also 603.

M'EWEN, E. 702

Training of engineers

The Engineer Vol. 208, 1959, 223

Unlike engineering, medicine has achieved the feat of being utilitarian and academically acceptable, and a highly paid, high status profession. It is pertinent to consider what the Medicals have that the engineer has not got. One important point is that medical staffs of universities practise medicine; another is that medical departments mobilise the best available talent, through part-time specialist lecturers. Engineering education would benefit from specialist contributions from practising

engineers, and from more interchange between university staff and industry. But an important issue is pay, as the part-time specialist would require adequate rewards. At the same time it is in the interests of the engineering industry to encourage improvements in the training of its graduate intake.

See also 204, 506.

TUCKER, D.G. 703

A broader education in a technological department

Universities Quarterly Vol.13(3), 1959, 157-63

It is a commonly held belief that the successful technologist is necessarily (or likely to be) a person of narrow interests. Recent work on broader education for electrical engineers at the University of Birmingham suggests that those students who do well in technical subjects also tend to do well in broader education subjects, where these have been given the same status as the technical subjects. It is encouraging to think that a successful technologist can also be seen as a person of high education, contrary to the popular perception.

BEAVER, Sir H. 704

Engineering and civilization

Proceedings of the Institution of Mechanical Engineers Vol.174, 1960, 1023-30

It is not only in engineering that specialisation and fragmentation are to be seen; it is probably a characteristic of all science. But it is most marked in engineering and the result is to weaken or conceal the conscious influence and impact that engineering has on society. One of the greatest problems facing engineers is to see how,in spite of specialisation in so many directions, a common purpose and ultimate worthwhile objective can be identified as being the real heart and justification of all engineering effort.

EDGEWORTH JOHNSTONE, R. 705

Some thoughts on engineering education

Nature Vol.193, 1962, 618-22

If an engineer is thought of simply as an applied scientist, it is difficult to avoid thinking of him as in some respects a second-rate scientist. This is inevitable because the methods of applied science are usually less rigorous and exact than those of pure science. The result is a somewhat depressed academic and public image of the engineer which is bad for the profession. But an engineer is not trying to do science; he is doing engineering, which is something different. The science he uses is a means to that end, and its quality as science is irrelevant so long as it works. In short, engineers are not second-class citizens in the empire of science; they are masters of an empire of their own, of which science is only a part.

See also 207, 606.

ALLANSON, J.T. 706

Engineering in the university

Education Vol.121, 1963, 1045-48

The popular idea of engineering is that it is a dirty and routine job, without the excitement of pure research, and this notion influences the choices made by sixth-form students. For this the university departments carry some responsibility because they have not taken seriously enough the job of explaining engineering to the schools. Engineers from universities and from industry should do much more to show the interest and variety of engineering. In addition, there ought to be more engineers teaching in schools, and industry and the universities should consider what action can be taken to encourage this.

See also 209.

CONWAY, H. 707

Engineers at the cross-roads

Advancement of Science Vol.21(92), 1964, 359-65

Unlike science, engineering has a poor image and is not regarded as one of the 'respectable' or desirable professions. While it may not be essential for the engineer to have a specially good image, it is essential for him not to have a bad one. Technology is too important for the poor image of the engineer to be allowed to continue as a handicap. Deliberate steps should be taken to raise the professional status of engineers, possibly through the Engineering Institutions Joint Council. There must be a method devised of rating qualified engineers of whatever discipline in such a way that the general public will know them for what they are by their designations.

PEARSON, Sir D. 708

The Present State of Engineering - Bridge between Science and Industry

Twelfth Fawley Foundation Lecture, University of Southampton, 1965

Engineers have a poor public image and this is possibly caused by four factors. The main reason is the lack of a precise definition of 'engineer', which is often substituted by 'technologist' to avoid an ambiguous image. But technology is seen as second-class science. Professional engineering activity is based on teamwork leading to the anonymity of leading engineers in contrast to the individuality of many professions. Engineers lack a single representative institution, although the formation of CEI may correct this deficiency. The status of engineers also suffers because there is no simple means of recognising graduate engineers in Britain. Degrees of B. Eng., M. Eng. and D. Eng. should be introduced generally to enhance the standing of engineering qualifications.

SNOW, Lord 709

The place of the engineer in society

Proceedings of the Institution of Mechanical Engineers Vol.180(1), 1965-66, 1259-62

One reason why engineers do not play the prominent part in society they should like is that they are not as fully educated as they should be. Two defects can be identified in engineering education. First, it does not encourage enough the speculative and rebellious

intelligence; as part of all engineering education there should be serious study of a subject which, of its nature, is bound to arouse the speculative mind. Secondly, the training lacks verbal quality and engineers, when they are not being engineers, are often handicapped because they have neglected or despised the use of words.

GERSTL, J.E. and HUTTON, S.P. 710

Engineers: The Anatomy of a Profession (Tavistock, 1966, pp.229)

Relations between science and engineering are similar in many countries, but for historical and social reasons the relative status of the two professions varies considerably. Where engineering enjoys higher status, it is partly explained by the more rapid and clear-cut development of engineering education in the countries concerned. Continental countries were ahead of Britain in establishing separate technical universities to train professional engineers during the 19th century. In Britain, because engineering departments were part of universities, for social and political reasons they did not grow as rapidly as they should have done. On the continent independent technical universities flourished, and as a result their status is higher than that of their British counterparts and the status of the engineering profession is much higher.

See also 108, 215.

BURROWS, C.R. 711

Educating engineers

The Engineer Vol.223, 1967, 372

The engineer's lack of status can be partly explained by the attitude of many engineers to theoretical knowledge, and is highlighted by the strong opposition to the increase in academic attainment required of engineers decided upon by the CEI. Since the difference between an HNC and a degree has not been recognised in engineering hitherto, it is not surprising that engineers have not enjoyed the status of doctors and other professional groups. The insistence on higher academic training must not, however, be considered to result from a desire for high status, but as an acknowledgement of the need for more rigorous theoretical training.

See also 608.

EARLE, A.F. 712

Management and the engineer

Proceedings of the Institution of Mechanical Engineers Vol.183(1), 1968-69, 739-44

If more engineers became managers it would improve the career prospects and status of engineering oriented work in two ways. It would cream off men in the senior engineering jobs and create more and quicker opportunities for reaching such jobs, and it would also ensure that a higher proportion of general management was sympathetic to engineering. If an engineering training combined with management education became one of the preferred routes to a general management position, both management and engineering would benefit.

See also 609.

MOON, J.A. 713

Professional ethics and education: a study of mechanical engineers

Vocational Aspect Vol.22 (53), 1970, 113-21

There has been considerable comment and discussion about the low status of engineers in society in comparison to other professional groups. It may well be that the true and proper evaluation of status lies in the social responsibilities of engineering. Many engineers have no personal philosophy of engineering because they have not been motivated by their education to consider the ethical and moral problems of engineering. If the engineering curriculum is solely technically centred, this may suggest the role of the engineer to be solely that of technical decision making. To enhance the status of the professional engineer education should enable him not only to be knowledgeable but also to make judgements about concepts he values in engineering.

SAMPSON, A. 714

The New Anatomy of Britain (Hodder and Stoughton, 1971, pp.731)

The unsatisfactory status of engineers may be partly explained by the fact that, the less practical scientists are, the higher is their prestige. The influence of engineers has been further limited by the fragmentation of the profession which has produced complicated internal rivalries. As yet the CEI is not a very high-powered body and the feuds between the sub-professions continue. During the 1960s engineers enjoyed a brief period of industrial and political influence as government sought to narrow the 'development gap' and foster the 'white hot technological revolution'. But the collapse of Rolls Royce proved to be a disaster not only for engineers in that company but for the whole engineering profession.

FORES, M.J. 715

Engineering and the British economic problem

Quest No.22, Autumn 1972, 21-23

The pay, if not the status too, of the professional engineer in Britain appears to be among the lowest in the developed world. Because the status of engineering in Britain is low compared with North-West European countries the quality of the new entrants to the profession is almost inevitably low as well. The result of this situation, in terms of professional quality, is that the average Swedish or Dutch engineer could, conceivably, be worth to his employer one and a half or two British engineers.

See also 117, 220.

RHODES, A.H. 716

Professional training and status of civil engineers

Proceedings of the Institution of Civil Engineers (Part 1) Vol.52, 1972, 355-78

If the civil engineer is to become the appreciated and recognised leader of society that he was in the last century, the standards of civil engineering education and training will have to be improved. Following the Robbins Report there was a dramatic increase in the number of undergraduate places in civil engineering but no equivalent

increase in entry standards to the civil engineering profession; this is at present the fundamental factor behind the profession's problems. Degree level courses should henceforth provide a first class academic training for the technician engineer and a good intermediate education for the professional engineer, who would proceed to a postgraduate diploma course. A firm control over the engineer to technician ratio will enhance the position of those who qualify as professional engineers.

POSSETT, H. 717

Attracting the best students to engineering

Proceedings of a National Conference on Engineering Education, ed. A.S. Goldberg (Education and Awareness, 1973), 13-16

Engineering has a poor image among school students. Therefore, the profession should emphasise the challenge of engineering (to serve mankind) and its inherent creativeness to appeal to the desire among young people to serve the community, a feeling which partly explains the swing away from science to the social sciences. A major problem currently exists in a lack of knowledge about engineering among school teachers, including science teachers; many still feel it is suitable only for second class intellects. Thus, there is also a need for good careers guidance to give young people the right information early on.

WEST, J.C. 718

Do we undervalue the engineer?

Project No.25, Summer 1975, 14-15

The poor image of the engineer is partly derived from our usage of the word 'engineer' to cover anyone from a plumber up to a professional chartered engineer. But the decline in the number of young people wanting to read engineering at a time when higher education is expanding by student demand suggests another problem. At present there is too much publicity given to the deleterious effects of the modern technological society. Too little attention is focussed on the fact that it is engineers who create the wealth and prosperity and who can do so much to help solve the problems of the modern world.

BAKER, Sir J. 719

The engineer and survival

Advancement of Science New Issue No.2, 2 September 1976, 2-6

The standing of engineering is not what it should be, largely because engineers are confused with scientists in the popular view, although engineering and science have little in common. The media, for example, devote some attention to engineering achievement, but without exception it will be described as another 'triumph for science'. As a good deal of glamour still surrounds science, this further distorts perceptions of engineering. Those involved in engineering activity have not been active enough in publicising, particularly at the level of secondary education, the challenge of engineering and explaining exactly how it differs from science.

See also 121, 223.

GLOVER, I.A. 720

Engineers - the forgotten profession?

The Chemical Engineer January 1976, 42-44

Not only are Britain's engineers poorly paid and held in low esteem, they are badly organised. In stark contrast to the medical and legal professions, engineers have traditionally been divided and weak, with new groups of specialists failing to be quickly assimilated alongside the older groups. Lack of collective unity is due in part to a situation in which practitioners are employed as middle-level technician-managers rather than as industry's generalists.

See also 224, 619.

THOMPSON, J.R. 721

The professional engineer in the 1990s

Proceedings of the Institution of Electrical Engineers Vol.123(1), 1976, 101-06

At present there are too few engineering students chasing far too many engineering courses. One factor in the declining number of students entering the engineering profession could be the poor rewards of the profession in the UK, in terms of both pay and status. Electrical engineering graduates are poorly paid by comparison with other graduates in this country, and very much worse off than their European counterparts. Engineers themselves can do very little about their status. Institutional or administrative action is unlikely to affect the issue. The change in attitude of the public to the professional engineer must be stimulated from outside the profession.

See also 336.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE 722

Education, Engineers and Manufacturing Industry

(University of Aston, 1977, pp.59)

Many high scoring 'A' level students elect to read engineering at degree level, but the overall average of 'A' level quality is reduced by a long tail of low-scoring candidates. To influence more of the more able students to choose engineering as a career will require changes in attitudes. School students perceive engineers, in manufacturing industry especially, to have a low salary, low status and low intelligence requirements compared with other professions. Various initiatives exist to counter this widespread attitude, but they will only have limited success as long as our society has a low opinion of engineering as a profession.

See also 337, 531.

FISHWICK, W. 723

The engineering professor's dilemma

Impact of Science on Society Vol.27(4), 1977, 369-77

In industrialised societies too high a proportion of good students have eschewed what they consider to be discipline-oriented subjects such as the physical sciences and engineering, preferring to study so-called mission-oriented disciplines in the social, earth and biological sciences,

as these are seen as more relevant to the solution of society's current problems. To attract good students engineering education must have a broad outlook, and consider the social as well as the industrial context of technology and technical innovation. Engineers must be educated so that they can participate meaningfully in any socio-ethical evaluation of a technology.

See also 338, 430, 620.

LANDON GOODMAN, L. 724

The status of engineers and engineering

Engineering, Technology and Society: Proceedings of Section X, British Association for the Advancement of Science, Lancaster 1976 (University of Aston, 1977),111-15

The Chartered Engineer is a creator, a synthesizer, working with and through people. He must recognise the social and economic consequences of his work, and the social and economic factors which determine what he does. If he fails to do so he loses his status in the eyes of the community. At present the educational system successfully produces technically qualified engineers, but they lack a broad perspective on their work. Thus, the nature of current engineering courses discourages applications from well-qualified students seeking a general education, and fails to produce the kind of engineers who could play a really effective role in the wider community.

See also 341.

LAWRENCE, P.A. 725

Engineers: the image and reality

Energy World June 1977, 2-4

Engineers do not have a good cultural image in Britain. Often they are seen as apolitical, uncritical or conformist in their social and political views, and sometimes as authoritarian and reactionary. Although there is no really substantial evidence to support this image, the issue has some practical import. If it is believed that engineers are reactionary and conformist this may disqualify them from leadership positions usually thought to require a broad base, flexibility, openness to ideas and general culture. This may, in part, explain why British engineers are under-represented in senior management posts compared with their colleagues in continental countries.

LAWRENCE, P.A. 726

The engineer and society

Energy World May 1978, 12-14

Engineering is a low status profession in Britain. The W.German example suggests a number of factors have an effect on the prestige enjoyed by engineers. The standing of the engineering profession and the status of industry are intimately connected. The way knowledge and skills are ordered and perceived influences professional status. Higher status is associated with training which is long, demanding and systematic, and with a qualification system which is clear cut and well understood by the general public. These factors work in favour of engineering in Germany, not so in Britain.

See also 227.

LOWREY, J. 727

Registration is coming but the big issue has been dodged

The Engineer Vol.245, 4 May 1978, 30

No amount of registration, licensing, accreditation, or legislation will resolve the inability of the professional engineer to project a favourable and positive image of himself. If engineers want status they must command it. They cannot expect to receive recognition as a professional body with a code of ethics, or imagine that they will lose the stigma of a mechanic or builder as long as they continue to apologise for their lack of status. The Finniston Inquiry is an attempt to make the engineer think about his position and demand the recognition and status that cannot be achieved by any committee recommendation but comes from a belief in himself and his profession. To date the profession has failed to engage in a 'great debate' along these lines.

MUIR-WOOD, A.M. 728

Presidential address 1977

Proceedings of the Institution of Civil Engineers (Part 1) Vol.64, 1978, 1-23

A low esteem for the engineer and his work is clearly evident in Britain. Such attitudes are as important as any factor in discouraging people of high ability from entering the profession. The question of status is secondary to esteem; if the engineer is esteemed and if he deserves the esteem, problems of status will evaporate. In the British educational system a hierarchy of esteem may be discerned in which engineering and other practical activities rank lower than classical or non-vocational disciplines. Within the system many fail to comprehend that the highest abilities are required by productive industry, on whose success the luxury of higher non-vocational education depends.

See also 228, 622.

BARNETT, C. 729

Technology, education and industrial and economic strength

Journal of the Royal Society of Arts, Vol.127, 1979, 117-30

British management is by comparison with its rivals especially weak in engineers, while recent research has suggested that there is a strong correlation between a country's industrial performance and the number of highly-qualified engineers in management. Moreover the percentage of professional engineers employed in production fell from 9% in 1966 to 6% in 1975. Our education relates to this in two ways. First, it fails to provide the right quantities and the right balance of appropriately skilled personnel for industrial capability. Secondly, the general thrust and ethos of British education are, if anything, hostile to industry and careers in industry. As a result too small a proportion of the national talent seeks a life in manufacture.

See also 345.

LAWRENCE, P.A. 730

Engineering and the national context

Electronics and Power Vol.25(5), 1979, 359-61

In so far as engineering is a body of knowledge and skill it is universal. But the way in which engineering work is conceived and the standing

of engineers themselves may vary from country to country. West German society confers rather more prestige on its engineers than is the case in Britain. The status of German engineers is enhanced by the length and rigour of their training. Moreover, the W. German undergraduate spends less time than his British counterpart on general engineering science, but more time on design and industry-related specialisms, while entry into industry is a stronger career choice in W. Germany than in Britain.

See also 231.

LAWRENCE, P.A. 731

Engineering education and meritocracy

Higher Education Review Vol.11(3), 1979, 27-35

The status of the engineering profession may be conceptualised as the product of a supply and demand equation. On the one side are the quality of engineers and the features of the education which produces them; on the other the labour market, its perceived needs, and its evaluation of the product of the education system. This equation operates in a socio-cultural context which also influences the status of engineers. It is difficult to change this context and impossible to change it quickly, and it also is difficult to change the demand half of the equation. Initiatives in Britain to promote engineering training are interventions in the supply sector, which is susceptible to change via legislation, policy and administration. However these cannot be guaranteed to produce the desired outcome - a situation in which industry wants engineers and is ready to promote them to important, well-rewarded positions.

POPE, J.A. 732

The role of universities in a changing technologically based industrial society

Journal of the Royal Society of Arts Vol.127, 1979, 610-26

At present a career in engineering or in any other field of industrial activity is not regarded as prestigious and therefore will always be at the end of the queue for the most able. That this situation is both unsatisfactory and dangerous is obvious but how the constraints, which make it inevitable, can be modified is very difficult to see. The value of successful manufacturing enterprises to society needs to be reaffirmed. Wealth creation depends on the manufacturing process, which in turn requires a major contribution from engineering. It is in manufacturing industry where most of our most able engineers need to be employed.

ALBU, A. 733

British attitudes to engineering education: a historical perspective. In *Technical Innovation and British Economic Performance*, ed. K. Pavitt (Macmillan, 1980), 67-87

It has been the historical lack of demand for engineers by the engineering and allied industries that has been the main cause of the low level of status, pay and, in particular, education of British engineers. What would now be called professional engineers were, until recently, mostly

ill-educated and received their training largely by apprenticeship. The only qualification available to the great majority was membership of one of the engineering institutions, in contrast to the degrees or diplomas given after full-time education to European or American engineers. The professional engineering institutions were slow to accept the necessity for full-time education and they have insisted that the practical training of the engineer was their responsibility, although they in fact had no means of ensuring that it was available and properly carried out.

See also 541.

HUTTON, S.P. and LAWRENCE, P.A. 734

German Engineers: The Anatomy of a Profession (Clarendon Press, 1981, pp.151)

In West Germany the quality of engineering education, access of engineers to management posts, status of industry, remuneration of engineers, and quality of new recruits to the occupation are all related in a circular interdependence. The question is how and where to break in to the British circle of low status and under-achievement? The optimal point for constructive intervention is the education system. This is partly because the realm of education offers some real opportunity to effect change, and partly because it is one of the few areas susceptible to direct government intervention. Measures which could be adopted are differential grants to favour engineering students; making the four-year degree course standard; and including some non-engineering elements in degree courses to counter the charge that engineers are narrow and lacking in non-technical interests.

See also 547.

PENNY, F.D. 735

Society and the chartered engineer

Proceedings of the Institution of Mechanical Engineers Vol.195, 1981, 357-68

Chartered engineers face particular difficulties in meeting the criteria for a high status profession. Their contact with those for whom they provide or help to provide goods and services is indirect and may be three or four levels removed from the consumer. So far as the consumer is concerned the chartered engineer will be anonymous. Worse still his loyalties are divided. The chartered engineer owes a duty to the organisation or firm which employs him, but he has an over-riding duty to the public for certain aspects of his work. To improve its standing the profession should take action on registration, educational standards, ethics, public service and public relations.

CHISHOLM, A.W.J. 736

Government financing of university engineering education (pt.2)

International Journal of Mechanical Engineering Education Vol.10(3), 1982, 185-94

Britain lacks the strong university professional schools, such as those of the German technical universities, which could provide an alternative focus to the dominant arts and classical tradition in her education system. In this arts culture relevant education for administration and management is thought unnecessary, while vocational higher education and training in subjects such as

engineering are thought inferior. Hence Britain's persistent failure to develop and sustain a really strong vocational component in her university education.

See also 135, 549.

CORFIELD, Sir K. 737

The making of an engineer

Journal of the Royal Society of Arts Vol.131, 1983, 390-401

Engineering can be seen as a liberal profession, which offers, as do the humanities, an excellent basis for living one's life as contrasted with earning one's living. To treat engineering as a remote or foreign body of knowledge is to ask for it to be developed elsewhere. Indeed, there are many signs that this is happening. New devices come from countries which have been quick to seize upon engineering as a way of life and whose values, to some regrettably material, are contributing to the creation of wealth from which, in turn, the other values, so highly prized in older societies, are themselves derived.

See also 137, 235.

KERENSKY, O.A. 738

The role of the Fellowship of Engineering

The Structural Engineer Vol.61A(10), 1983, 308-09

During this century, the standing and image of engineers has declined and their influence on national affairs and major economic decisions is less than it should be. There are many educational and social reasons for this situation, and one of the basic ideas behind the prestigious 'Fellowship of Engineering' was to uplift the standing of engineers. However, status cannot be acquired artificially. When engineers take a greater part in public affairs and become known as engineers, their status will be enhanced. Through the study of their art, engineers should be well fitted to participate in shaping society's response to the effects of technological change.

MILLER, K. 739

The role of the Engineering Council

The Structural Engineer Vol.61A(10), 1983, 306-08

Unlike those in other industrialised countries British manufacturing companies have a low proportion of engineers on management boards and in key decision-taking posts. The Engineering Council is taking action to try and secure a better balance of skills and recognition of technological needs at the highest levels in manufacturing companies. Thus the Council has produced guidelines on appraising the commercial and technical practices of companies, as leading investment institutions, such as pension funds and insurance companies, have become interested in the evaluation of these aspects of industrial firms.

See also 138.

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